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ORIGINAL PAPERS

FORMATION OF MULLITE FROM CYANITE, ANDALUSITE, AND SILLIMANITE[1]

BY J. W. GREIG

ABSTRACT

This paper deals with a thermal and microscopic study of the decomposition of cyanite, andalusite, and sillimanite to mullite and silica, or to mullite and a siliceous liquid. The rates of alteration, the signs of the heat effects accompanying the changes, and the way in which the decompositions take place have been investigated.

The bearing on refractories is discussed.

HISTORICAL

It has long been known that both cyanite and andalusite are altered when heated to high temperatures. Saussure,[2] who first described the mineral cyanite, noted as early as 1785 that, on heating, the transparent mineral lost its color and became opaque white with a mat surface and a somewhat open texture, so that it was easily crumbled. In 1801 Haüy[3] noted that andalusite became white on heating. In 1889[4] and 1890[5] Vernadsky

[1] Recd. June 4, 1925. Presented at the Annual Meeting of the AMERICAN CERAMIC SOCIETY, Columbus, Ohio, February, 1925.

[2] Saussure, "Voyage dans les Alpes," Vol. IV, *Neuch.* (1796), pp. 84–5.

[3] Haüy, *Traité de minéralogie*, **3**, 269 (1801).

[4] W. Vernadsky, "Note sur l'influence de la haute température sur le disthuène," *Bull. soc. franc. Min.*, **12**, 447–56 (1889).

[5] W. Vernadsky, "Sur la reproduction de la sillimanite," *Bull. soc. franc. Min.*, **13**, 257 (1890).

described experiments on cyanite. He heated the mineral in a gas furnace and found that it first lost its color, remaining transparent, and then, at a temperature of 1320–1380° measured with a Le Chatelier pyrometer, it altered quite sharply to the material described by Saussure. This took place in from 10 to 20 minutes and further heating had little effect. He states (1890) that the change takes place with liberation of heat. The product was studied in thin section and found to consist of needle crystals with positive elongation. The density was determined as 3.15–3.23 (1889). From these facts and from the fact that he was unable to affect sillimanite by heating he concluded that cyanite is changed to sillimanite and that the change is irreversible. He states (1890) that andalusite is also altered to sillimanite at the same temperature with a liberation of heat.

In 1902 Beekman[1] repeated Vernadsky's experiments on heating these minerals. He determined the density before and after heating and his results agree well with Vernadsky's. Going farther, he measured the refractive index γ of the supposed sillimanite formed from cyanite, and found this to be 1.62, much too low for sillimanite. From this he concluded that cyanite does not form sillimanite on heating.

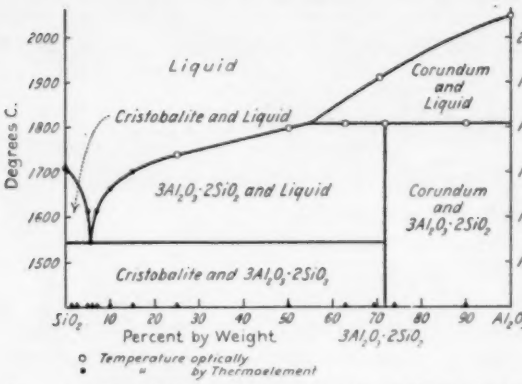


FIG. 1.—Equilibrium diagram of the system alumina-silica. Bowen and Greig (*op. cit.*).

In 1909, Shepherd, Rankin, and Wright[2] heated both cyanite and andalusite for various lengths of time at different temperatures. They concluded that andalusite at high temperatures changes to sillimanite, but very slowly. Cyanite they found to change more rapidly than andalusite. They were unable to identify the product as sillimanite under the microscope but concluded, on the basis of Vernadsky's density determination, that it was probably sillimanite. They were unable to detect any heat effect accompanying the change.

It has recently been shown by Bowen and Greig[3] that sillimanite itself

[1] E. H. M. Beekman, "Over't gedrag van distheen en sillimaniet op hooge temperaturen," *Verslagen Wisen Natuurk. Afd., Kon. Akademie van Wetenschappen Amsterdam*, **11**, 295–7 (1902).

[2] E. S. Shepherd, G. A. Rankin, and F. E. Wright, "The Binary Systems of Alumina with Silica, Lime and Magnesia," *Am. J. Sci.*, **28** [4], 293–333 (1909).

[3] N. L. Bowen and J. W. Greig, "The System Al_2O_3–SiO_2," *Jour. Amer. Ceram. Soc.*, **7** [4], 238–54 (1924).

is unstable at high temperatures and that the only compound of alumina and silica which is stable above 1050°C is the compound $3Al_2O_3.2SiO_2$ which has been named mullite.[1] (Fig. 1.)

Shortly after this Peck[2] published a paper in which he described, very briefly, the use of andalusite in the manufacture of porcelain, and the changes produced in andalusite and cyanite during firing. The result is described as an aggregate of needles of mullite with glass between. The needles are parallel in the case of andalusite and interlocking in the case of cyanite. The alteration of andalusite is said to take place sharply, at a definite temperature, and to be accompanied by a decrease of volume.

EXPERIMENTAL WORK

The three minerals cyanite, andalusite and sillimanite have the composition $Al_2O_3.SiO_2$. They differ, however, in physical properties, and in mode of occurrence. Mullite has the composition $3Al_2O_3.2SiO_2$: in physical properties it resembles sillimanite, and, to a lesser extent, andalusite. Since mullite is the only compound of alumina and silica stable at high temperatures, its formation is to be expected when any other compound of these oxides is heated to a high enough temperature. The work to be described here is a thermal and microscopic study of the decomposition of the compound $Al_2O_3.SiO_2$.

All three minerals cyanite, andalusite and sillimanite were investigated in two ways: *First*, charges of the powdered mineral were heated in a platinum-wound electric furnace, at a constant temperature, for a definite length of time, and the charge, after removal from the furnace, examined with the petrographic microscope. The temperatures were measured with a Pt:Pt 10% Rh thermocouple and a White potentiometer. *Second*. Heating curves were made using a differential thermocouple in series with a high sensitivity galvanometer.

Investigation by Heating at Constant Temperature

Cyanite The cyanite used was the beautifully transparent, slightly bluish material which occurs in a paragonite schist at Pizzo Forno near St. Gotthard. The crystals were carefully selected to be free from all foreign matter and, after crushing, the powder was examined under the microscope to be sure of its purity.

Cyanite has two perfect cleavages: the best is parallel to *a* (see sketch Fig. 2), the other parallel to *b*. There is also a parting parallel to *c*. On

[1] N. L. Bowen, J. W. Greig and E. G. Zies, "Mullite, a Silicate of Alumina," *Jour. Wash. Acad. Sci.*, **14**, 183–91 (1924).

[2] A. B. Peck, "Note on Andalusite from California: a New Use and Some Thermal Properties," *Am. Mineralogist*, **9**, 123–9 (1924).

grinding, the mineral breaks up into plates and lath-shaped flakes with surfaces determined by these planes. When the powder is mounted for examination under the microscope, either before or after the heating, the majority of the grains lie on the *a* plane, others on the *b*. The results obtained by heating cyanite at constant temperature are summarized in Table I.

TABLE I

DECOMPOSITION OF CYANITE BY HEATING

Run	Temp., °C	Time, hrs.	Results determined by microscopic examination
1	1000	48	Unaffected
2	1100	48	Exceedingly slight decomposition to mullite + silica on some parts of the surfaces of the grains
3	1160	2	Decomposition less than in 2
4	1240	1	Decomposition greater than in 2
5	1335	1	Mullite crystals 0.002 mm. (approx.) in length
6	1360	1/4	Mullite crystals 0.01 mm. (approx.) in length
7	1360	1/2	Mullite crystals 0.02 mm. (approx.) in length
8	1360	3/4	Mullite crystals 0.035 mm. (aapprox.) in length
9	1410	1/4	Crystal of cyanite 4×4×10 mm. completely decomposed to mullite + silica

Examination of the material from run 4 (1 hr. at 1240°C), in a liquid whose index matched one of the principal indices of the cyanite, showed that it was quite unaffected by the heating except that on the surfaces of the grains were minute areas the index of refraction of which had been lowered. The amount of these areas varied in different grains from approximately 0.1 % to 5% of the surface.

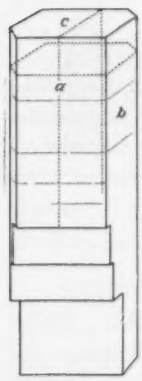


FIG. 2.—Sketch of a crystal of cyanite. The dotted lines show the orientation of sections shown in Figs. 8 and 9.

Examination of the material from run 5 (1 hr. at 1335°C) showed that practically all the surfaces, except those parallel to the *a* face were altered to the new material and that the alteration had advanced into the grain, forming a fringe estimated as 0.002 mm. wide. The surfaces parallel to the *a* face are not so much altered as the others. The interior of the grains is quite unaffected cyanite, as can be seen by grinding the powder so as to expose fresh surfaces to the immersion liquid.

When the alteration has progressed farther, as in runs 6–9, it can be seen that the new material shows exceedingly minute needles arranged parallel to each other in tiny bundles. The bundles are themselves not far from parallel (Fig. 5) and are nearly perpendicular to the surfaces from which they commenced to grow, whether these surfaces are parallel to the cleavage planes or not. The individual needles are too small in diameter to be resolved by the microscope but give the material a fibrous appearance. (See Fig. 4.) Needle crystals,

then, are one of the products of the alteration: they commence at the surfaces and advance into the unaltered cyanite. The rate of growth or advance of these needles depends on the orientation: the needles that lie in the plane of the best cleavage, that is, the *a* plane, advance several times as rapidly as do those perpendicular to it.

The rates of growth of these needles, and of decomposition of the cyanite increase rapidly with temperature as shown in Table I. The length of mullite crystals given in the table is the average width of the zone of altered material measured on grains lying on the *a* plane. (See Fig. 4.)

It is believed that the product of the alteration is an intimate mixture of mullite, $3Al_2O_3.2SiO_2$, and silica, for the following reasons. It is known from the work of Bowen and Greig[1] that mullite is the only compound of alumina and silica stable at these temperatures. The index of refraction of this alteration product was measured by the method of immersion on material from run 8: it is 1.625 ±.002 for sodium light with "vibration plane" parallel to the elongation of the needles. Beekman[2] obtained 1.62 for this index on his material. Referring to the upper part of Fig. 3, it will be seen that the observation agrees well with this interpretation whatever the form of the silica. The sign of elongation of the needles also agrees, being positive. A charge of cyanite was held for 22 hours at 1520°C: due to this long heating at a high temperature the silica was collected into minute pellets. (See Fig. 7.) The index of refraction of the other phase could now be measured fairly closely

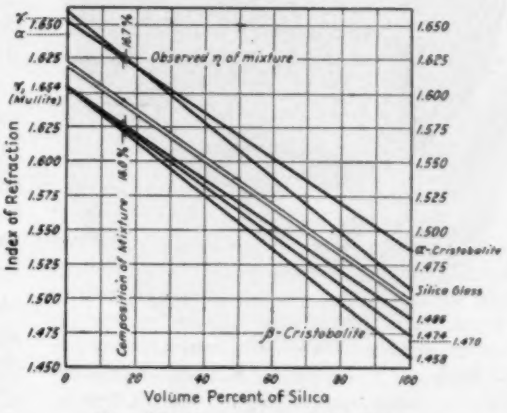


FIG. 3.—Upper part of diagram.

The index of refraction of silica glass and of α-cristobalite are joined to the observed value of the index of the product of decomposition of cyanite. At the composition of mullite the prolongations of these joins agree well with the index γ (1.654) of that compound.

Lower part of diagram.

The index of refraction γ of mullite is joined to the indices of refraction of different forms of silica. The intersections of these joins with the volume percentages of silica in the mixture give the index of refraction that such a mixture would have. These are to be compared with the observed index 1.625 ± 0.002.

[1] *Op. cit.*

[2] *Op. cit.*

FIG. 4.—Cyanite heated 30 minutes at 1360°C × 500. The grain is lying on the *a* plane. The line of demarcation between the altered material and the unaltered central portion is clearly shown. The individual needles of mullite are not distinguishable but the fibrous structure can be made out. The clefts due to differential expansion can be seen running in from the corners.

grain when decomposition is complete. (Figs. 4, 5, 6.) This indicates that the expansion is greatest in the direction of elongation of the mullite needles.

Crystals of cyanite were found to act as described by Saussure[1] on heating. A transparent crystal of bluish cyanite was heated with the powder in run 6 ($^1/_4$ hr. at 1360°C). After heating the color had largely disappeared. The crystal was otherwise megascopically unchanged. Examination under the microscope showed that it had behaved exactly as the powder: the index of refraction of the

[1] *Op. cit.*

and was found to agree with that of mullite. Dr. Wyckoff of this Laboratory has very kindly made X-ray photographs, by the powder method, of finely ground cyanite which had been heated to 1400° for 30 minutes. The pattern obtained was identical with that from mullite.

The change from cyanite to mullite and silica involves a very considerable expansion. This increase in volume causes a cleft to form at the edges of the grains of powder between the *b* and *c* cleavage faces: the clefts advance inward with the development of the mullite. They are frequently joined by a split down the center of the

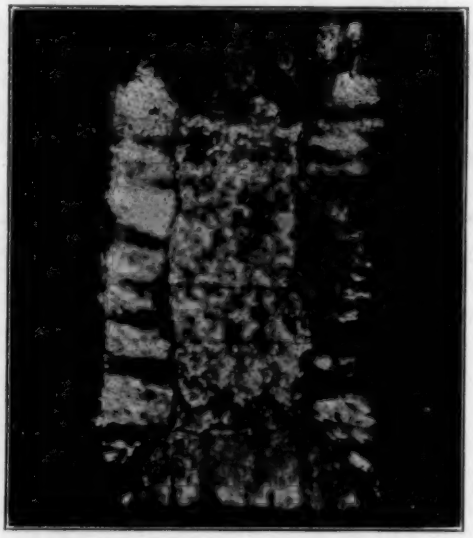


FIG. 5.—Cyanite heated 45 minutes at 1360°C, crossed nicols, × 300. This photograph brings out the orientation of the grains in bundles which are almost parallel to each other and perpendicular to the surfaces from which they grow

cyanite had not changed but mullite had developed perpendicular to surfaces and cleavage cracks.

The crystal from run 9 (1/4 hr. at 1400°) was white and opaque: it was easily crumbled between the fingers.

The observation made here, that cyanite remains unaltered, save for the loss of color, at whatever temperature it is heated, until it decomposes to mullite and silica as described above, is in entire agreement with the observations of Shepherd, Rankin, and Wright,[1] who found it unchanged after being heated for 2 days at 1000°C. It does not agree with those of Beekman,[2] who shows a progressive decrease of index of refraction after heating, for which I am unable to account. His conclusion, however, that cyanite does not form sillimanite on heating is borne out by this work.

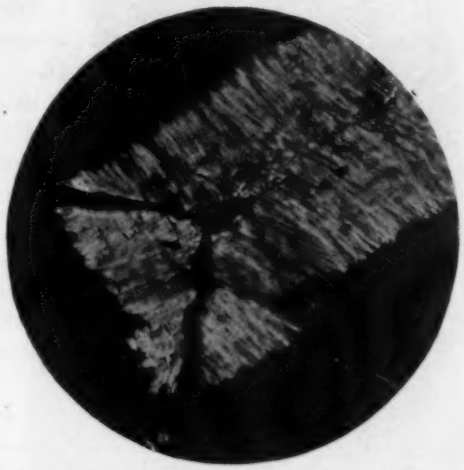


FIG. 6.—Cyanite, decomposed at 1400°C, crossed nicols, × 300. The clefts due to differential expansion are shown: the split down the center shows in places.

FIG. 7.—Cyanite heated 22 hrs. at 1520°C × 600. The small dots are cristobalite. Compare with Fig. 4.

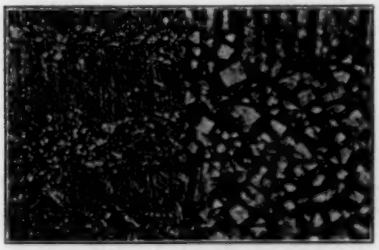
When cyanite is heated to temperatures above 1545°, the temperature of the eutectic between cristobalite and mullite (see Fig. 1), there is not the same regularity of structure as observed in charges heated below that temperature. There is some liquid present at the high temperatures and the crystals of mullite grow much larger. (See Figs. 8 and 9.)

Andalusite Transparent crystals from

[1] *Op. cit.*

[2] *Op. cit.*

Minas Geraes, Brazil, were used. These crystals have a brownish color and are free from inclusions. The powder was examined under the microscope before being used and found to be quite free from foreign matter.



a *b*

FIG. 8*a*.—Cyanite heated ½ hr. at 1760° C × 100. The section is cut parallel to the *c* face. Note the layers of parallel mullite needles.

FIG. 8*b*.—Same as 8*a*, × 600.

The results of the runs at constant temperature are summarized in Table II.

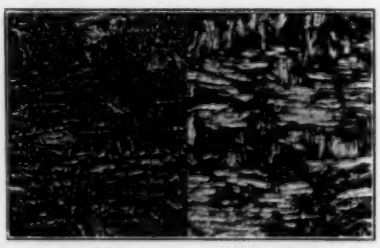
Examination of the material from run 1 (1 hr. at 1325°C) in a liquid whose index matched one of the principal indices of andalusite showed less than 1% of the grains to be affected at all. These few had minute dots of a material of low index of refraction developed on some of the surfaces. The amount is exceedingly small.

TABLE II

DECOMPOSITION OF ANDALUSITE BY HEATING

Run	Temp., °C	Time, hrs.	Results determined by microscopic examination
1	1325	1	Practically unaffected
2	1410	1	Some decomposition to mullite + silica
3	1500	2¾	Decomposition is greater than in 5 and less than in 6
4	1530	½	Mullite needles 0.005 mm. in length
5	1530	1	Mullite needles 0.01 mm. in length
6	1530	1½	Mullite needles 0.02 mm. in length

In the material from run 2 (1 hr. at 1410°C) all the grains are affected. The alteration is confined to surfaces more or less perpendicular to the *c* axis of the original andalusite. On parts of the edges of some of the grains the isotropic zone described below can just be made out by using the sensitive tint plate. The rest of the grain is perfectly homogeneous, unchanged andalusite.



a *b*

FIG. 9*a*.—Cyanite heated ½ hr. at 1760°C × 100. The section is cut parallel to the *b* face.

FIG. 9*b*.—Same as 9*a*, crossed nicols, × 100.

In the material from runs 3–6 it can be seen that, when completely decomposed, the grains consist of mullite with minute dots and filaments of some material of low index which is believed to be silica. The mullite can be readily determined by measur-

ing the index of refraction by the method of immersion. This is most easily done on small grains as the silica makes the larger ones somewhat opaque.

The mullite commences to develop at the surfaces of the grains and grows inward. The newly developed mullite is always oriented with the $\acute{c}$ axis parallel to that of the original andalusite. Since the sign of elongation of mullite is positive and that of andalusite is negative, there is a zone in which the "path difference" due to the advancing mullite is equal and opposite to that due to the remaining andalusite. This causes a dark band when the grain is examined between crossed nicols. (See Fig. 10.)

The grains formed by grinding andalusite are not, as in the case of cyanite, bounded by definite planes: they lie, under the microscope, with all orientations. Consequently it is difficult to form an idea of the length of mullite needles developed in any preparation. It is not certain, therefore, that all the grains of andalusite decompose at the same rate. The lengths given in the table are to be considered as an estimate and are more likely too low than too high.

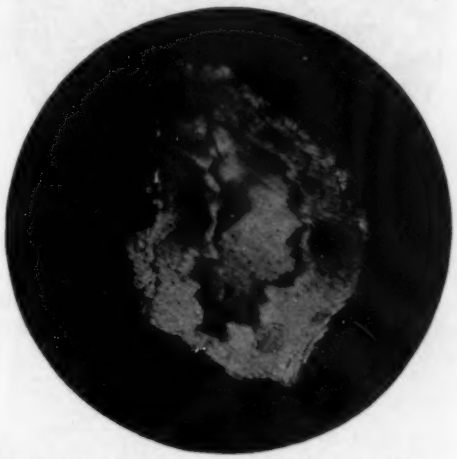


FIG. 10.—Grain of andalusite partly decomposed, crossed nicols, × 250. The uniform orientation of the mullite can be seen by the parallel lines due to the silica between the needles. The dark band shows where the "path difference" due to the mullite cancels that due to the remaining andalusite.

Table II brings out the fact that, just as in the case of cyanite, andalusite decomposes to mullite and silica over a considerable range of temperature and that the rate increases rapidly with increase of temperature. Thus these alterations cannot be said to be sharp or to take place at a definite temperature.

When heated to temperatures above that of the eutectic between cristobalite and mullite there is liquid present, and the mullite needles grow much larger, the structure remaining the same. (See Figs. 11 and 12.)

The alteration of andalusite to mullite and silica, or mullite and glass, causes the crystals to become opaque and white like porcelain, as noted by Haüy[1] and many mineralogists since. This is due to the fact that it is then composed of two substances of widely different indices of refraction

[1] *Loc. cit.*

intimately mixed together. As noted by Peck,[1] the alteration of andalusite does not cause the crystal to break up mechanically or become friable as in the case of cyanite.

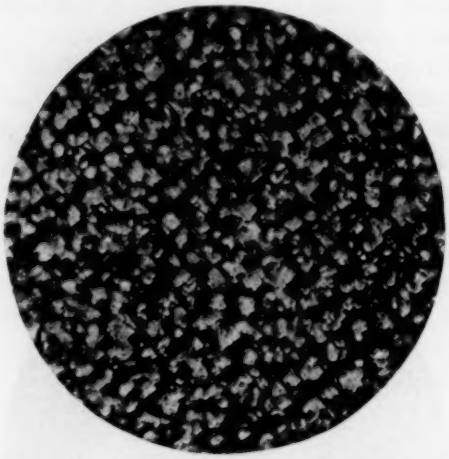


FIG. 11.—Andalusite crystal after heating at 1750°C × 500. The section is cut perpendicular to the ϵ axis. The mullite crystals are shown with square cross-sections parallel to each other. The dark interstitial areas are glass.

The results in Table III show that here again the rate of decomposition increases with temperature.

Unlike the other two cases, decomposition does not appear to commence at the surface of the grains of sillimanite: it appears to take place throughout the grain. A charge of powdered sillimanite raised to a temperature of 1685°C at a rate of 9°C per minute, and immediately removed from the furnace, was examined and compared with the original sillimanite. Scattered sparsely throughout the grains were

Sillimanite The material used was the very pure fibrous sillimanite from Delaware County, Pennsylvania. It was carefully selected, and when examined with the microscope before use was found free from foreign matter.

It has already been shown[2] that sillimanite remains unchanged when heated for long periods of time at temperatures below 1545°; but that it decomposes above this temperature, yielding mullite and liquid, and that the newly developed mullite is oriented parallel to the original sillimanite.

FIG. 12.—Andalusite crystal heated to 1750°C × 600. The section is cut parallel to the ϵ axis of the original andalusite and of the developed mullite. The dark areas are glass.

[1] *Op. cit.*

[2] Bowen and Greig, *Op. cit.*

TABLE III

DECOMPOSITION OF SILLIMANITE BY HEATING

Run	Temp., °C	Time, hrs.	Results determined by microscopic examination
1	1345	150	Unaffected
2	1550	11	A small amount is decomposed to mullite + glass, but crystals of mullite are too small to be resolved by microscope
3	1625	3	Definitely decomposed—mullite + glass
4	1665	1	Decomposed, individual crystals of mullite readily distinguishable
5	1750	3½	Decomposed, mullite crystals average about 0.003 mm. in diameter

minute pellets of glass. The mass of the material was, however, homogeneous and the index of refraction was slightly lower than that of sillimanite but much higher than that of mullite. Were it completely changed to mullite and glass the index would be lower than that of mullite. It can be accounted for as an intimate mixture of unaltered sillimanite and the products of decomposition. As heating is continued the typical structure is developed: needles of mullite arranged with their $\acute{c}$ axes parallel to each other and to that of the original sillimanite with liquid between. (See Figs. 13 and 14.)

Megascopically, sillimanite changes on decomposition to a white, porcelain-like material. As with andalusite, there is no mechanical disintegration accompanying the change even when the mineral is in large pieces.

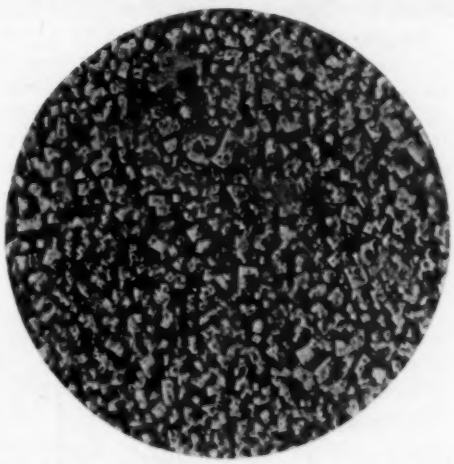


FIG. 13.—Sillimanite heated to 1750°C × 500. The section is cut parallel to the base. The square cross-section of the mullite crystals is shown. The original sillimanite was not a single crystal, but the variety known as fibrolite; hence the mullite crystals are oriented with only their $\acute{c}$ axes parallel.

Thermal Effects Accompanying the Alteration

Method of Investigation

This method of investigation consists in making heating curves by means of a differential thermocouple. A charge of the material under investigation is placed in one half of a divided crucible, and in the other a charge of some reference material known to exhibit no thermal effects in the region

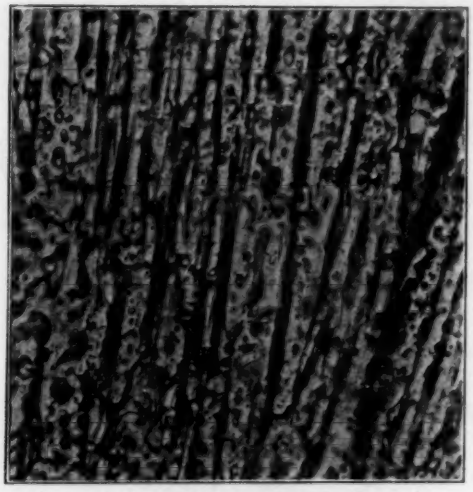


FIG. 14.—Sillimanite heated to 1750° C × 600. The section is cut parallel to the c axes of the original sillimanite and of the developed mullite. Before firing the sillimanite of this photograph and of Fig. 13 was perfectly homogeneous. It is now composed of two things, mullite crystals, showing light in the photograph, and glass, which is dark. These photographs demonstrate in a very convincing way that sillimanite and mullite are different compounds.

under investigation. Readings are taken alternately on the temperature and difference of temperature at regular and frequent intervals, while the temperature of the charges is raised. The apparatus used is shown diagrammatically in Fig. 15. The thermocouple used was Pt:Pt 10% Rh, arranged as shown. When the switch S_1 is down, the temperature of the charge may be read on the potentiometer; when up, the electromotive force due to the difference of temperature of the two charges causes a current to flow through the high sensitivity galvanometer G_2. The difference of temperature is read in terms of the deflection of this galvanometer. In order to keep this deflection always at a conveniently small amount, an electromotive force opposed to that of the differential element may be introduced in the circuit. The resistances R_2 and R_3 are adjusted so that a change of setting of 1 on the resistance R_1 causes a convenient deflection of the galvanometer G_2; in this case equivalent to 5 cms. on the scale. As used the scale could be easily read to $^1/_2$ division: one division corresponded to about 0.014°C. The charges, with the thermocouples

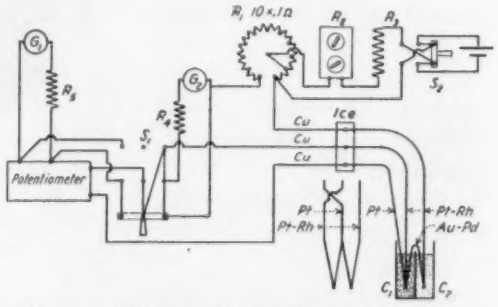


FIG. 15.—Diagram of apparatus used in differential heat runs. S_1, switch opening and closing temperature and differential circuits. S_2, switch to reverse direction of e. m. f. introduced in the differential circuit. R_3, resistance of 20,000 ohms. R_2, resistance of 9900 ohms variable in steps of 100 ohms. R_4 and R_5, damping resistances of galvanometers G_2 and G_1, respectively. C_1, charge of material under investigation. C_2, charge of reference material.

carefully centered in them, were heated in a platinum or platinumrhodium-wound electric furnace. The heating rate was not kept constant, but the resistance in series with the furnace was decreased at a constant rate: in most of the runs 0.01 or 0.02 ohm every fifteen seconds. Readings were made every fifteen seconds alternately on temperature and difference of temperature.

In each case the reference material was corundum made by firing pure precipitated alumina at a temperature in the neighborhood of 1600°C.

Cyanite

A number of runs were made on the same cyanite as used for the work at constant temperature. In each case it was found that decomposition was accompanied by a marked absorption of heat, and that there were no other thermal effects. No effect is obtained on a second heating.

A typical curve is shown in Fig. 16.

As would be expected from the data of Table I, the exact position of the maximum on the curve depends on the size of grain and rate of heating. The temperatures of this maximum in different runs were 1395°, 1399°, 1399°, 1402°, 1422°. The highest temperature was obtained with a heating rate of 10° per minute.

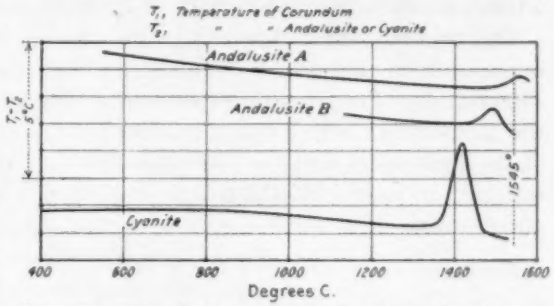


FIG. 16.—Plot of runs made with differential thermocouple, showing the heat absorption accompanying decomposition.

While this work was in progress Houldsworth and Cobb[1] published a differential heating curve made on cyanite from 0° to 1200°C. This shows an absorption of heat between 775°C and 850°C. The change to which this is due is irreversible. On the basis of the results of the study at constant temperature it is difficult to see how such a change could be possible in cyanite. An irreversible change would almost certainly leave some mark on the cyanite but the microscope reveals none. Moreover, no sign of any such effect was found with the differential element. There is no record of any microscopic examination of the material they used, and, as this mineral is particularly liable to contain foreign matter, it is thought probable that the effect observed was due, not to the cyanite, but to something else contained in it.

[1] H. S. Houldsworth and J. W. Cobb, *Trans.* [English] *Ceram. Soc.*, **22**, 111–37 (1923).

Andalusite The material used was the same as in the work at constant temperature. As was shown by that work, andalusite alters much more slowly than cyanite and at a higher temperature. A number of runs were made on andalusite which showed only a very slight change of slope in the region of the eutectic between cristobalite and mullite (1545°C). Since the alteration proceeds from the surface inward, the smaller the grain, the shorter will be the time required to alter it completely. Curve A, Fig. 16, is a plot of a run on finely ground andalusite. It shows a definite heat absorption but it is above 1545°C. It was believed that this was due to the decomposition, so a charge was prepared by grinding andalusite for 36 hours with a mechanical grinder, and then floating off the finest material for use. The preparation was examined with the microscope and found free from contamination: the average grain was less than 0.001 mm. in diameter. The run made on this material is plotted as curve B, Fig. 16. This time there is a quite definite heat absorption below 1545°. Microscopic examination, after the run, showed that the material had been completely decomposed. The alteration, then, takes place with an absorption of heat.

The thermal effect observed in the case of cyanite and of andalusite is opposite to that which Vernadsky (1890) states accompanies the decomposition. He gives no experimental details except that he measured the temperature with a "Le Chatelier pyrometer." Considering the sign of the heat effect and the difficulty experienced in detecting it with the sensitive apparatus used in this investigation, I am at a loss to explain his observations.

Sillimanite Finely ground sillimanite was also run to see if any heat effect could be observed. No effect whatever was observed below 1545°C.

Form of Silica Present in the Product of the Decomposition

When cyanite and andalusite are decomposed by heating they yield mullite and silica: mullite 87.64%, silica 12.36%, calculated for the pure mineral. The question arises, then, as to what form the silica is in, whether amorphous or crystalline; and if crystalline, in which modification. On account of the fine state of subdivision of the silica and its dispersion in the mullite the form cannot be determined with the microscope.

Both tridymite and cristobalite when heated undergo inversions at low temperatures.[1] An attempt was made to decide the question by detecting the heat effect accompanying these inversions. The apparatus was that described above; but for this work a Pt 10% Rh: Au 40% Pd differential

[1] C. N. Fenner, "The Stability Relations of the Silica Minerals," *Am. J. Sci.*, **36** [4], 331–84 (1913).

thermocouple was used. (Fig. 15.) This is about five times as sensitive as the Pt: Pt 10% Rh couple, but cannot be used at temperatures much above 1400°C. With this arrangement one division of the scale corresponded to a temperature difference of 0.003°C.

The results of this investigation are summarized in Table IV.

TABLE IV

RESULTS OF DIFFERENTIAL HEAT RUNS ON DECOMPOSED CYANITE AND ANDALUSITE

Run	Material	Microscopic examination	Result of heat run
1	"Cyanite" heated ½ hr. at 1400°	No silica visible	No thermal effect observed
2	"Cyanite" heated 20½ hrs. 1400–1415°	Little different from 1. Some silica has collected into grains large enough to be seen	No thermal effect observed
3	"Cyanite" heated 22 hrs. 1520° ±10°	Silica has now collected into minute pellets	Very slight effect corresponding to $\alpha \longrightarrow \beta$ cristobalite inversion
4	"Andalusite" heated 5 hrs. 1520° ±10°	Silica in minute pellets and shreds	Very slight effect corresponding to $\alpha \longrightarrow \beta$ cristobalite inversion
5	"Andalusite" heated 20 hrs. 1520° ±10°	As 4	As 4

Runs 3, 4 and 5 are plotted in Fig. 17. Although the heat effects are exceedingly small, they are real, for they are obtained each time the charge is heated. The temperatures at which the maximum heat effect was observed in different runs are given under the diagram. Considering the fast heating rate employed and the magnitude of the heat effect, the agreement is good. By comparing the break in these curves with that on

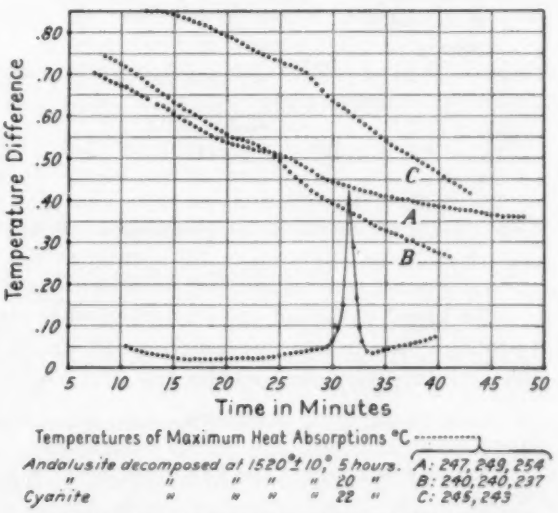


FIG. 17.—Plot of runs made on decomposed cyanite and andalusite to detect inversion of the silica. In each case the first value was obtained for the run plotted. The lower curve is a plot of a run made on a mixture containing cristobalite 12%, corundum 88%.

the curve obtained with a mixture of 12% cristobalite and 88% corundum it will be seen that only a very small part of the silica inverts. That which does invert is cristobalite. If the rest is crystalline it must remain in the high-temperature form.

Dr. Wyckoff has kindly made X-ray powder photographs of the material used for all these runs except 5. The following are the results.

(1) No pattern except that of mullite.

(2) There is a very faint broad line which is not due to mullite. It is not definite enough to say whether it is due to cristobalite or to tridymite.

(3) A sharp, well-developed line corresponding to the most prominent line of the cristobalite pattern. It is not possible to state whether the cristobalite is in the α or β form. From the intensity of the line there is a considerable amount present; probably all the silica is there as cristobalite.

(4) Could not be certain whether or not there is any line other than those due to mullite.

TABLE V

CORRESPONDENCE OF CALCULATED WITH OBSERVED INDEX OF REFRACTION OF THE PRODUCT OF DECOMPOSITION OF CYANITE

Form of silica assumed	Density	Volume % of silica	Index of refraction	Index of refraction of mixture	
				Calculated	Observed
α-cristobalite	2.333[1]	16.0	1.486[1] (mean)	1.627	
β-cristobalite	2.277	16.4	1.474	1.625	
α-tridymite	2.270[1]	16.4	1.471[1] (mean)	1.624	
β_2 tridymite				1.624	
Silica glass	2.206[2]	16.7	1.458[3]	1.621	
Index of product of decomposition of cyanite					1.625 ±0.002

Density of mullite 3.156.

Index of refraction γ of mullite 1.654.[4]

Values for β-cristobalite calculated on basis of 2.4%[5] volume change at the α-β inversion.

The change in tridymite at the inversion is too small to affect the value of the index of refraction of the mixture in the third decimal.

There is a progressive increase in the size of the grains of silica in 1, 2 and 3. The broad nature of the line obtained in the X-ray photograph of 2 is probably due to the exceedingly small size of the crystals of silica. If these crystals were still smaller the line would not be detected.

[1] C. N. Fenner, "The Stability Relations of the Silica Minerals," *Am. J. Sci.*, **35** [4], 331–84 (1913).

[2] Day and Shepherd, "The Lime-Silica Series of Minerals," *Am. J. Sci.*, **22** [4], 276 (1906).

[3] J. W. Gifford and W. A. Shenstone, "The Optical Properties of Vitreous Silica," *Proc. Roy. Soc.*, **73**, 201–8 (1904).

[4] Bowen and Greig, *op. cit.*

[5] P. Braesco, "Étude des points des transformation par une methode dilatometrique," *Ann. Phys.*, **14**, 5–75 (1920).

As stated above the index of refraction of the material formed when cyanite is decomposed was measured and found to be $1.625 \pm .002$. Since the index is an average of that of the silica and γ of the mullite, it depends on the form in which the silica is present. In Table V are given the results of a calculation of the indices that the mixture would have with the various forms of silica. This is not a very sensitive test, yet it shows that the silica can hardly be there in the amorphous form: the most probable form is β-cristobalite or one of the forms of tridymite. This is shown graphically in the lower part of Fig. 3.

From the X-ray photograph of the "cyanite" of run 3 the silica is probably all cristobalite and from the results of the heating runs made on this material it is nearly all β-cristobalite. From the data on refractive index this is also the most probable modification of the silica formed immediately on decomposition of cyanite. Although, at the temperature at which this material was formed (1360°), tridymite is the stable form,[1] it is in entire agreement with experience with silica that cristobalite should crystallize instead of tridymite under such conditions. It is believed, therefore, although the evidence is not as full as might be desired, that the silica set free when cyanite is decomposed by heating is crystalline, most probably cristobalite, and that it remains in the high-temperature form on cooling, due to the extremely small size of the crystals. When these crystals grow larger, due to long heating at high temperatures, some of them invert on cooling as in the material of run 3 (heated 22 hrs. at 1520°).

Since the thermal behavior and state of aggregation of the silica in 4 and 5 (Table IV) are very little different than in 3, it is probable that, in the case of andalusite, the silica is cristobalite, only a small amount of which inverts on cooling, the rest remaining in the β-form.

Volume Changes Accompanying the Alterations

The density of mullite, made from the pure oxides by repeatedly sintering at a temperature of about 1700°C and grinding, was found by the pycnometer method to be 3.156 at 30°C. The density of silica and of the glass formed at temperatures above 1545° is much less. The densities of cyanite, andalusite and sillimanite are, according to Dana, 3.56–3.67, 3.16–3.20, 3.23–3.24, respectively. The alteration of these minerals by heating must therefore be accompanied by an increase of volume. This is greatest in the case of cyanite and least in that of andalusite. The values obtained by Vernadsky (1889) and by Beekman[2] show this increase. Peck,[3] on the other hand, states that the alteration in the case of anda-

[1] Fenner, *op. cit.*
[2] *Op. cit.*
[3] *Op. cit.*

lusite is accompanied by a decrease of volume, but gives no measurements.[1]

APPLICATION TO REFRACTORIES

Since the three minerals, cyanite, andalusite and sillimanite are available as sources of material for the manufacture of alumina-silica refractories a knowledge of their behavior on heating is of value to ceramists. All three are themselves quite refractory but the fusion temperature of ware made from them can be raised by the introduction of alumina. This is well brought out in Fig. 18, which is the equilibrium diagram on which the weight percentage of mullite present at different temperatures has been marked. It is to be noted that the volume percentage of mullite present is considerably less than the weight percentage. By addition of alumina the composition of the compound mullite is approached, and, since this remains unaffected up to the temperature of its incongruent melting, the amount of liquid present at any temperature is decreased.

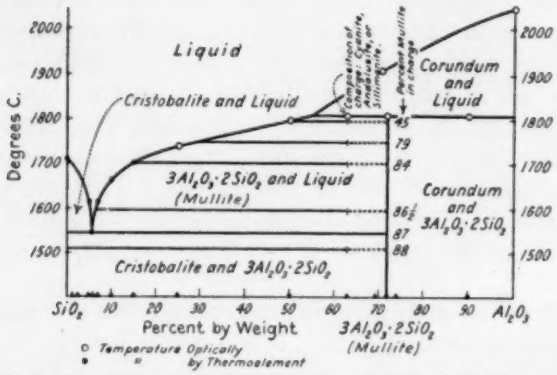


FIG. 18.—Diagram showing percentage by weight of mullite formed by heating sillimanite andalusite or cyanite.

The expansion of cyanite during the alteration to mullite and silica is so great that any ware made largely from this mineral would probably be shattered on firing. The difficulty may be overcome by changing the mineral to mullite and silica before forming it into ware. The data of Table I show that this is most readily done at temperatures above 1400°C and that then a few minutes will suffice for even quite coarse material. Since the material becomes very friable during the alteration it can be more easily ground afterward than before.

With either andalusite or sillimanite no trouble due to expansion is to be expected.

Since the silica does not invert on cooling, there is no likelihood of trouble from volume changes due to it.

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[1] While this manuscript was in press Peck published density determinations which show an increase in volume. (A. B. Peck, "Changes in the Constitution and Microstructure of Andalusite, Cyanite and Sillimanite at High Temperatures and Their Significance in Industrial Practice." *Jour. Amer. Ceram. Soc.*, **8**, 407–29 (1925).)

SUMMARY

The three minerals, cyanite, andalusite and sillimanite are decomposed, on heating, to mullite and silica, or to mullite and siliceous liquid. The silica is probably cristobalite.

The lowest temperatures at which the alterations take place are different for the three minerals: cyanite alters at the lowest temperature, sillimanite at the highest. For all three there is no definite temperature at which the mineral decomposes sharply to the new phases, and below which it remains unaffected for an indefinitely long period.

In the cases of cyanite and of andalusite the alteration commences on the surfaces of the grains and advances inward. In that of sillimanite the change seems to take place throughout the grain.

In all three minerals the rate of decomposition increases rapidly with rise of temperature.

When andalusite and sillimanite are decomposed, the newly formed mullite crystals are oriented parallel to the original crsytals: with cyanite this orientation is determined by the surfaces from which the mullite grows.

The decomposition of cyanite and of andalusite is shown to be accompanied by an absorption of heat.

In all three cases the new phases formed are of lower density than the original mineral, so there is an expansion accompanying the decomposition.

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DISCUSSION

D. W. ROSS: In the case of the cyanite, you speak of the crystal in the dry powder. When they are in the melt how do they develop? Does it radiate out in the melt?

J. W. GREIG: Whether the cyanite, or the mullite which is developed on decomposition of the cyanite, will be attacked by the melt will depend on the composition of the melt, and on the temperature. I have not investigated the effect of a melt on the decomposition of cyanite. In the course of the work I have just outlined I have examined a thin section of cyanite over which the liquid, formed by melting a low grade fire brick, had flowed. The decomposition had taken place precisely as if there were no melt present, that is, as shown by the photographs. The liquid had penetrated the openings in the crystal, formed by cleavage cracks and fractures; into the liquid, which filled these openings and surrounded the crystal, long needles of mullite had radiated from the decomposed cyanite. In general I should expect that, at temperatures above 1300°C, the decomposition of the cyanite would proceed as in the dry powder and that whether or not there was attack on the mullite would be determined by the

composition and temperature of the melt. Mullite is stable in contact with melts of silica and alumina, with smaller amounts of other oxides, through quite wide ranges of temperature and composition.

I have not investigated the rate of attack of mullite by melts in which it is not stable.

W. J. McCAUGHEY: Does the color change?

J. W. GREIG: These minerals have various colors before being heated. When they are decomposed, they are all perfectly white, and opaque-like porcelain.

W. J. McCAUGHEY: How do you tell easily sillimanite from the mullite?

J. W. GREIG: The easiest way is to know where it comes from. There has been sufficient work done to demonstrate that in all ceramic ware the needles are mullite, not sillimanite. In rocks they are usually sillimanite, but not always. To decide the question they must be removed from the matrix. This may be done by leaching in *cold* hydrofluoric acid followed by other acids to dissolve the products of the reaction. The index of refraction of the individual crystals may then be measured by the method of immersion. This will usually settle the question. It is true that mullite may contain titanium and iron and the indices of refraction may be raised by them, approaching those of sillimanite. In such cases we have found the mullite to exhibit a pink pleochroism; sillimanite rarely if ever shows this pleochroism. Another method, which is not generally available to mineralogists, but which is quite decisive, is to fire the cleaned crystals to a temperature of 1600°C or 1700°C. If the crystals are mullite they will be unaffected; if sillimanite, they will be decomposed to mullite plus glass, and an examination under the microscope will readily decide the question. A fuller discussion of these points will be found in the two papers, "The system Al_2O_3–SiO_2," by Bowen and Greig[1] for last year, and "Mullite, a Silicate of Alumina," by Bowen, Greig and Zies.[2]

[1] *Op. cit.*

[2] *Op. cit.*

PROGRESS REPORT ON THE USE OF ANDALUSITE AS A REFRACTORY[1]

By Robert Twells, Jr.

ABSTRACT

An account is given of the development of andalusite for refractory purposes with descriptions of some uses to which it has been put.

Introduction

History

The discovery of a large deposit of andalusite and the development of its use on a commercial scale makes a story which sounds like a romance. The results, however, were only attained through patient search, thoroughly scientific research and careful plant control, extending over a period of years. The use of andalusite in producing the "sillimanite" spark plug porcelain has been most successful. In fact many new and valuable results have been attained which could not have been foretold. The Champion Porcelain Company is, of course, chiefly concerned in the use of andalusite in heat-resistant vitrified porcelains. An interesting development, however, has been the use of the andalusite as a refractory. This work is still in the experimental stage and final results are not yet available.

The Andalusite

The andalusite herein mentioned has been fully described by Peck[2] and the description need not be repeated. Suffice it to say that the deposit is found at an elevation of 10,000 feet on White Mountain of the Inyo range in California. Its composition is that of a rather pure andalusite with comparatively small amounts of several associated minerals of which corundum and pyrophyllite are perhaps the chief. Quartz is confined chiefly to small veins crossing the mass, and is readily sorted out. "Generally the material runs at least 75–85% andalusite upon microscopic examination. A typical chemical analysis from a sample representing a carload shipment, recalculated to an Al_2SiO_5 basis, will show over 90% Al_2SiO_5. Such an analysis follows:

Analysis		Equivalent to	
SiO_2	33.78	Al_2SiO_5	94.18
Al_2O_3	56.89	SiO_2	0.22
H_2O	0.37	Others	5.60
Ignition loss	3.67		
Other determining constituents	5.37		
	100.08		

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb. 1925. (White Ware Division.) A partial report of some work carried on by several persons over a period of time in the Research Department of the Champion Porcelain and Jeffery-Dewitt Insulator Companies.

[2] A. B. Peck, "Note on Andalusite from California; A New Use and Some Thermal Properties," *Am. Mineralogist*, **9**, 123 (1924). This article has been freely drawn upon for microscopic and mineralogical information.

The fact that the chemical analysis generally shows higher Al_2SiO_5 than is indicated by the microscopic examination is due to the frequent occurrence of corundum in the material."

Physical Changes on Firing

The behavior of andalusite under firing is important. "Up to its inversion point andalusite retains all of its original optical properties except for the formation of small glass-like inclusions which apparently represent the fusion of included impurities." At about cone 13 "the clear homogeneous grains of andalusite give way to grains composed of fibrous or columnar crystals, each crystal parallel to the adjacent one with a narrow strip of glass between. The result is instead of a clear grain, a grain composed of a group of parallel crystals having all of the optical properties of $3Al_2O_3.2SiO_2$, with a highly siliceous glass between each."

During inversion the andalusite does not outwardly loose its original form. In fact it is possible to exactly refit together the jagged edges of two halves of a lump of andalusite, one half just as it came from the mine, the other half after being fired to cone 18. This constancy of volume is a most important advantage of andalusite. For comparison cyanite expands greatly at its inversion point (about cone 11) and breaks down to a chalky friable mass. On the other hand some highly aluminous refractories such as diaspore and bauxite have the tendency to shrink continuously under load at high temperatures.

Change in Chemical Constitution

When the original work to utilize andalusite was started its ratio, 1 Al_2O_3 to 1 SiO_2, was thought to be ideal for refractory purposes. Bowen and Greig[1] have since shown that the ratio of $3Al_2O_3$ to $2SiO_2$ makes theoretically the better refractory for very high temperatures. This superiority is due, not so much to the relatively small difference in their fusion points as to the fact that the 1:1 ratio starts to melt at a much lower temperature due to the formation of $3Al_2O_3.2SiO_2$ crystals and a highly siliceous liquid.

As Bowen and Greig explained, for many refractory uses, the presence of a small amount of siliceous liquid may even be desirable owing to its bonding strength and low coefficient of expansion. Its high viscosity would also tend to prevent ready deformation under load. At somewhat moderate temperatures andalusite refractories can thus be expected to be fairly constant in volume, resistant to fracture by thermal changes, and stronger under load than fire clay refractories. For very high temperatures it might be desirable to mix diaspore or bauxite with the andalusite in amounts sufficient to give the entire refractory the $3Al_2O_3.2SiO_2$, or mullite ratio.

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[1] N. L. Bowen and J. W. Greig, *Jour. Amer. Ceram. Soc.*, **7** [4], 238–54 (1924).

The natural mullite itself has unfortunately not yet been discovered in a commercial deposit. Andalusite on the contrary is available in large quantities at moderate cost. The deposit is exceptionally uniform and pure, making concentration unnecessary.

Use of Andalusite as a Refractory

Load Capacity Its softening point under load, although doubtless lower than that of mullite, is still high enough to make andalusite useful for many special refractories. In a standard load test conducted at the Mellon Institute, a standard size, 100% raw andalusite brick gave a deformation of 0.38%. At the same time a sample No. 1 grade fire brick gave a deformation of 4.36%.

Fusion Point Standard cone tests of the andalusite indicate a fusion point between cones 35 and 36. It should be recalled that this deposit of andalusite is being developed primarily for its properties in a high fire porcelain. Some samples of andalusite picked especially on account of their purity gave still higher fusion tests.

Molding Property Another important property of andalusite is the ease with which it can be formed into difficult shapes. The pyrophyllite present is no doubt of considerable help in the development of plasticity and bond at this stage. Most of the andalusite refractories tried have been formed by hand tamping in steel or wooden molds. In some cases a wall or floor was rammed directly in place in a kiln or furnace. It was found practical to form a mix consisting of 100% andalusite by the use of a small amount of organic bond. Such a mixture could no doubt be readily worked in a dry press machine. Casting special refractories from andalusite was readily done with the addition of small percentages of clay. In this way several difficult shapes such as spouts and stoppers were made for glass refractories.

Bonding Experiments were made covering the use of many different bonds for the andalusite grains at high temperatures. At present, when the refractory is made by tamping, the grains are allowed to bond themselves. This they readily do when fired to about cone 18. It is thus unnecessary to use plastic bond clays which would tend to weaken the load bearing properties of the mixture.

A Service Test The refractory problem at the Champion Porcelain Company has always been very difficult. High fire porcelains are usually fired on a very short schedule. One tunnel kiln is now being operated on a 31-hour cycle. Oil is used to produce a firing temperature of cone $18^1/_4$ down. In continued use under such conditions the best flint or highly aluminous fire brick will soften and bulge under relatively small load.[1]

[1] This approximates 10 lbs. per square inch or less at about 1450°C.

The rapid thermal changes in this plant are also very trying on the refractories. Fire clay car tops break up rapidly, their average life being from 3 to 4 months. Under these severe conditions andalusite blocks are now being used for the tops of practically all of the cars. The first of these cars has been running continuously since November 7, 1924. So far the blocks are in good condition, showing no signs of cracking or softening.

Two mixes are being tried out in this way, one coarse and one relatively fine. The mold used had the dimensions $13^{7}/_{8}''$ by $6^{15}/_{16}'' \times 2^{1}/_{2}''$. The fired blocks made of the fine mix were exactly the same size as the mold; those of the coarse mix were $14'' \times 7'' \times 2^{1}/_{2}''$. The absorption of the fine mix was 7.8%, that of the coarse mix 6.5%. A very fine mix is somewhat difficult to mold due to its springy nature; cracks form in molding which tend to open in firing. A coarse mix tends to expand slightly in its initial fire. A properly proportioned mix is not subject to these defects.

Andalusite Saggers As a sagger at this plant andalusite has not yet proved satisfactory due to the failure of the bottoms when filled with ware. The same may also be said regarding fused alumina, fused or calcined artificial sillimanite or mullite, spinel, zircon and such "super-refractories" with the exception of silicon carbide.

The reasons for these failures are the design of the saggers and the severe conditions under which they are used. The saggers themselves have a $^{5}/_{8}$-inch thickness of wall and bottom and an inside diameter of $13^{1}/_{2}$ inches. Over this span they must carry a load of about 8 pounds at a temperature of cone $18^{1}/_{4}$ down. Some saggers were made having sides of andalusite and bottoms of silicon carbide; these proved to be very good.

The andalusite at cone $18^{1}/_{4}$ down seems to have good strength in compression but is somewhat weak in tension or shear. A large number of mixes were made up to try to overcome this defect. These were tamped into $9^{1}/_{4} \times 2^{5}/_{8} \times {}^{3}/_{4}$-inch bars which after an initial fire were given sag tests across an 8-inch span. The cone was noted at which sagging commenced.

The best results (cone $19^{1}/_{2}$) in this test were obtained with mixes containing from 50% to 75% of calcined andalusite, the balance fine raw andalusite. In mixes containing all raw andalusite the fine grained bars stood the sag test better than the coarse grained. Clay and similar binders did not prove advantageous.

The temperature used during the initial fire of the bar proved to be important. The higher the first fire the better were the results.

None of the "super-refractories" already named, except silicon carbide, stood this test successfully at cone $18^{1}/_{4}$ down. In fairness, however, it should be stated that no attempt was made to use these "super-refractories" for saggers except under the severe conditions already mentioned. At

lower temperatures, with saggers of different design we understand that some have been quite successful.

The best andalusite mixes developed would doubtless also stand up successfully in ordinary practice at cones 8 to 12 and might prove considerably better than the ordinary fire clay-grog sagger. A large whiteware manufacturer is now testing out the andalusite in this respect.

Andalusite in Standard Brick

A considerable number of standard size brick were made from a 100% andalusite mix similar to that tested at the Mellon Institute. One installation is in an oil fired test kiln frequently used for firing ware at cone 32. The andalusite brick form the side walls; high grade silicon carbide brick form an arch over the fire box and a double baffle wall at one end of the kiln chamber. The silicon carbide brick are now badly blistered. The baffle wall has twisted and partly fallen over. This would indicate that there had been an intense local heat at that part much higher than cone 32. The andalusite brick are now dark brown in color. There are some shrinkage cracks at intervals in the joints, otherwise the walls appear sound. The cracking may have been due partly to the fire clay mortar which was used.

With andalusite refractories we are now using a mortar made of 100% finely ground andalusite. This mortar works well and gives a thin joint. Other andalusite brick have been placed in installations which cannot yet be examined; for instance, in the fire boxes of a tunnel kiln and of boilers.

Andalusite as a Plastic Refractory

Another installation of andalusite was a rammed-up lining in a rotary brass smelting furnace. Previously several different kinds of refractories, including high temperature cements had been tried with poor results. The andalusite proved more successful than the others, and gave good satisfaction.

Conclusions to Date on the Value of Andalusite as a Refractory

Silicon carbide stands in a class by itself in resisting shearing loads at high temperatures; andalusite, however, seems to compare equally favorably in this respect to the remaining "super-refractories." The most valuable properties of andalusite are its constancy of volume, its good strength under compressive loads at moderately high temperatures, its resistance to sudden heating and cooling, and the ease with which it can be shaped and bonded. It is to be expected that the chief uses of andalusite as a refractory will be in places where lack of volume changes and resistance to thermal shocks are the most important requisites.

CHAMPION PORCELAIN CO.
DETROIT, MICH.

Discussion

F. H. RIDDLE: The andalusite[1] used is from the Inyo Mountains in California.

J. W. GREIG: I have seen some of this material: it has suffered considerable alteration, not on the surfaces only, but throughout the crystals, particularly to pyrophyllite, and I was wondering if this alteration caused it to be more easily formed than pure andalusite. Pure andalusite when powdered will not be plastic.

F. H. RIDDLE: Mr. Twells stated the pyrophyllite was a tremendous help in developing a little plasticity.

E. SCHRAMM: Is this material generally available, or is it going to be?

F. H. RIDDLE: Not yet, but there is a deposit there that will eventually be big enough so that it probably could be. So far, it has been used just for experimental purposes in different lines.

K. M. SMITH: Of what use can andalusite be made in whiteware such as sanitary ware? Would it be of advantage to use it in the prevention of dunting or spalling or would its color alone throw it out?

F. H. RIDDLE: The color of this particular deposit would throw it out. It fires to quite a dark tan color. However, there are parts of the deposit which are practically pure white and the treating of this particular deposit would possibly make it of use.

K. M. SMITH: Would additions of this pure andalusite be of benefit to the sanitary ware at the ordinary sanitary temperatures cones 9 or 10?

F. H. RIDDLE: In a comparison of the thermal expansion of quartz and of this material and of the bodies in which these materials are used there will be a noticeable difference in favor of the andalusite. Whether it will be of any benefit is something that has to be proven out. Small experiments look favorable, but large scale production has not been attempted as yet other than at high fires. Above cone 15 it is absolutely all right. However, down below that, it looks very favorable.

J. W. GREIG: What percentage of pyrophyllite was found in this material?

A. B. PECK: There is an average of about 5%. It varies a good deal. There are little pockets where there is a great deal; then there is a lot of material that is practically pure and uncontaminated.

J. W. GREIG: What is the difference, after it has been raised to a high temperature, between this material and fresh andalusite from other sources?

A. B. PECK: Microscopically there is no difference between the two; apparently though, it works better.

[1] A. B. Peck, "Note on Andalusite from California: a New Use and Some Thermal Properties," *Am. Mineralogist*, **9**, 123–9 (1924).

J. W. GREIG: Is it better than cyanite or sillimanite?

F. H. RIDDLE: From our experience it is very much better, but we have naturally shown more interest and have gone after our particular material a great deal more intensively than we have things which were not available commercially.

J. W. GREIG: These refractories really are not andalusite after they have been fired, but are mullite plus siliceous glass or silica. One made from cyanite or sillimanite would be the same in this respect.

F. H. RIDDLE: The ease with which they change to the mullite and excess silica and the temperatures at which they make that change also have a marked effect on the quality of the product. There is a noticeable difference.

We have made synthetic mullite. The mullite crystals are very sharp, fine grain crystals and very much more difficult to work than is this material.

J. W. GREIG: This andalusite would be much easier to work into ware because of the impurity which is in it than would pure mullite.

F. H. RIDDLE: It so happens that this andalusite has some fluxes in it, and these fluxes are the fluxes which are beneficial to a porcelain in which you wish a high hot dielectric resistance at higher temperatures. There are no alkalis whatever present, at least only traces, and of course, in this particular case it is a great advantage, but for refractories, as Mr. Twells stated, a different type of andalusite from the other parts of the deposit would be preferable or else this one purified.

J. B. DAVIS: Does andalusite have any effect on platinum? Would it make platinum wire brittle or cause it to crystallize?

J. W. GREIG: Andalusite, free from iron, will have no effect on platinum. We have used tubes of this composition on which to wind the platinum of our electric furnaces, and there has been no action on the platinum. These tubes were not made from andalusite, but are of practically the same chemical composition.

F. H. RIDDLE: We have made up tubes of 1:1 mixtures vitrified at cone 32 and have had very good success with them. It is really very refractory and yet gas-tight and so prevents impurities from getting through the tubes and attacking the platinum.

J. W. GREIG: Marquardt porcelain, the material to which I refer, is of practically the same composition. Some grades contain more alumina, approaching the composition of mullite, while others are nearer the 1:1 ratio of sillimanite. They contain very little in the way of impurities. This material, when fired, is composed of mullite needles with interstitial siliceous glass, the same as refractories made from andalusite. This porcelain is a very satisfactory refractory to support the platinum winding of an electric furnace. There is no reaction between the refractory and

the platinum. At the Geophysical Laboratory there are furnaces built in this manner that have been in use for years.

R. TWELLS, JR.:[1] The development of andalusite as a refractory has progressed considerably since the presentation of this article in February. As car top blocks for the Harrop kiln cars, the andalusite is very good. Whereas the fire clay brick or blocks tend to shrink and warp badly on repeated firings through the kiln, the andalusite blocks hold their size and shape exceptionally well, nor do they tend as readily to vitrify and crack.

For refractory uses at about cone 18 it has been found desirable to add a small percentage of plastic kaolin to the andalusite to facilitate molding. As was stated in the article, it is readily possible to mold a 100% andalusite mix; however in production on a larger scale the additional bond gives added strength and reduces the loss in the green state.

Some good results are being attained at cone 18 with andalusite saggers having the lower halves of the bottoms made from silicon carbide. The thin layer of silicon carbide acts as a reinforcement to help support the weight of the ware. Contrary to what would be expected, the andalusite and silicon carbide bond together fairly well in this way. Some of these saggers have been through the tunnel kiln 10 times and are still in fair condition. The andalusite sides seem to resist cracking better than the regular silicon carbide saggers. For use as a sagger for temperatures about cone 10 it would be unnecessary to use a reinforcement of silicon carbide. The experience at the Champion Porcelain Company with some mixtures containing about 50% andalusite and 50% plastic kaolin would indicate that similar combinations would have very good lives as saggers at the temperatures used in most whiteware plants.

The Research Department of the Champion Porcelain Company is now working on some extensive experiments to study the characteristics of andalusite products under different conditions. The results of this detailed work will no doubt be made available later.

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[1] Recd. June 1, 1925.

FUNDAMENTALS OF HEAT FLOW IN MOLTEN GLASS AND IN WALLS FOR USE AGAINST GLASS[1]

By George V. McCauley

ABSTRACT

This paper deals with the flow of heat through molten glass and through glass retaining clay walls. Reference is given to previous work on heat flow by convection, radiation and conduction as applied to clay refractorise. Experimental data are given for *conductivity of flux block*, and for the *effective conductivity of molten glass* as a function of temperature. Photographs are presented to show *existence of convection currents in a glass tank.*

Introduction

Method of Analysis

In considering the heat flow through molten glass and retaining clay walls, it is often customary to regard the problem as analogous to the flow of electricity through a series of conductors of different resistances. Thus temperature difference becomes analogous to difference of potential and quantity of heat per unit of time, analogous to current. The quotient of temperature difference by quantity of heat per unit of time then corresponds to thermal resistance. It is further customary to use such units as will express quantities of heat in watt seconds or watt hours. This method while simple in theory has its limitations when one wishes to express by means of curves, the flow of heat as a function of temperature existing in the glass, refractory and outside air. The reason for these limitations is that the thermal resistance factor is too often a complex function of the temperatures themselves and not of the temperature difference or thermo-motive forces involved. Therefore in our discussion we shall employ the older method of analysis and divide the problem into heat flow by conduction, convection and radiation. From this viewpoint very little can be added to the excellent treatment of Professor Trinks in his book on "Industrial Furnaces."

I. Heat Flow in Tank Blocks

Heat Flow from Outside of Block

At the outside surface of a tank block a definite temperature of equilibrium is established depending upon the inside tank temperature, the velocity and temperature of outside cooling air, and the thermal conductivity of the block. Assuming a temperature of Θ_0 for this outside block temperature and a temperature of Θ_a for the cooling air, a definite heat flow passes from the block to the air. This flow takes place by convection, radiation and possible conduction through a thin layer of air.

Heat Flow by Convection

A number of experimenters from Newton's day to the present have sought to establish the relation between heat flow by convection, both

[1] Presented at the Annual Meeting, Columbus, Ohio, Feb. 1925. (Glass Division.)

natural and forced, and the temperature difference between solid body and moving fluid. Everyone, of course, is familiar with the statement of Newton's law of cooling. Boussinesq[1] from theoretical considerations showed that heat loss by convection is directly proportional to the temperature difference between surface and moving fluid. Rayleigh[2] also shows this from dimensional analysis or principle of similitude. This has been verified in the case of cylindrical bodies at least, by King[3] and others.

For natural convection, Lorentz[4] gives us the theoretical law for convection at a flat vertical surface. This states that heat loss is proportional to the five-fourths power of the temperature difference between plate surface and moving air. This is in agreement with the empirical formula developed by Dulong and Petit[5] and has since been verified by the work of Langmuir[6] and of the National Physical Laboratory.[7]

The results of these investigations from theoretical considerations and experimental verification, show that for a given velocity of air, heat flow by convection is proportional to the five-fourths power of the temperature difference between solid surface and moving fluid. The dependence on velocity has not been so firmly established although the later experiments especially of Langmuir, indicate a heat flow proportional to the velocity for a given temperature difference between surface and moving air. Combining the work of Wamsler,[8] who finds the convection loss from rough surfaces to be approximately 90% of that from smooth surfaces, with that of Langmuir as done by Professor Trinks[9] we may express flow of heat by convection in still air by the relation

$$Q_v = .25\,(\theta_0 - \theta_a)^{5/4} \qquad (1)$$

where Q_v denotes the quantity of heat in B.t.u. flowing per hour per square foot of surface from the block into the surrounding air by convection alone. The term "convection" is here used to denote the complete manner of heat flow from block surface to air other than that accounted for by radiation. Heat flow by radiation is known to take place in accordance with the laws of Kirchhoff and of Stefan-Boltzman. Thus the quantity of heat flowing

[1] *Comptes Rendus*, **133**, 257 (1901).
[2] *Nature*, **95**, 66 (1915).
[3] *Phil. Trans., R. S.*, **214**, 373 (1914).
[4] *Ann. der Phys.*, **13**, 582 (1881).
[5] *Ann. d. Chim. Phys.*, **7** (1817).
[6] *Trans. Am. Electrochem. Soc.*, **23**, 299 (1913).
[7] Report on "Heat Transmission by Convection and Radiation," published by the Food Investigation Board (1921).
[8] *Zeits. d. V. D. I.*, p. 599 (1911).
[9] "Industrial Furnaces," p. 63.

by radiation from a unit area of surface at temperature Θ_0 per unit of time to a surrounding absorbing medium at temperature Θ_a is given by

$$Q_r = Ak_r \{(\Theta_0 + 460)^4 - (\Theta_a + 460)^4\} \quad (2)$$

where A denotes the absorbing power of the block surface to black body radiation and k_r is the total radiation constant expressed in B.t.u. per square foot per hour from a surface at 1°F absolute to a medium at 0° absolute. The constant A is likewise the factor of proportionality by which we need multiply black body radiation to give the radiation of a body at the same temperature as the black body and whose absorption coefficient is A.

The constant k_r has been determined by a great many investigators and the present adopted value of 5.46×10^{-12} watts/cm.^{2}/deg.^{4} becomes 1.64×10^{-9} in our units of B.t.u. per hour per square foot per °F.[4]

For the constant A, Wamsler finds the value .96 for rough wrought iron surface; and this is also probably quite applicable to clay block surfaces.

Assuming this value for the absorption coefficient of clay block and combining the expression of heat flow by radiation and convection we have

$$Q_s = 1.57 \times 10^{-9} \{(\Theta_0 + 460)^4 - (\Theta_a + 460)^4\} .25 (T_0 - T_a)^{5/4} \quad (3)$$

By means of this relation it is now possible to compute for various air temperatures, the total heat flow per hour per square foot from a block surface as a function of the temperature of this block surface. Such curves are shown in Fig. 1.

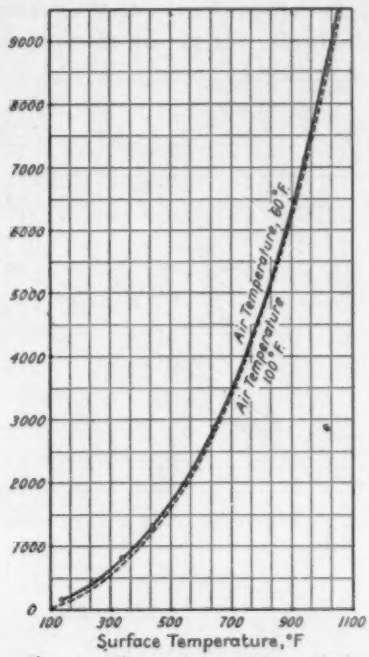

FIG. 1.—Flow of heat by radiation and convection from rough vertical surface. Heat flow (B. t. u. per sq. ft. per hr.).

Heat Flow by Conduction

The same quantity of heat which flows per hour per square foot from the block to the surrounding air must also pass in the same time per square foot through the block. The passage here, however, is by conduction. In the majority of cases, the problem is one of the simplest in heat conductivity. The flow is in one direction only, and can usually be regarded as independent of time. The flow is thus said to be linear and steady. The flow under these conditions is given by the relation

$$Q_c = \frac{k(\Theta_1 - \Theta_0)}{L} \qquad (4)$$

Q_c denotes the heat flow by conduction in B.t.u. per square foot per hour, where k is the coefficient of thermal conductivity, L is the thickness in inches and Θ_1 and Θ_0 are the temperatures of hot and cold surfaces of the block respectively.

Practical Application Since the heat flow as given by relations (3) and (4) are identical we may combine the two to help us predict any one of three things connected with the heat flow through the block. If we can measure the two surface temperatures of the block, we are in a position to compute the value of k, the thermal conductivity of the block. This may prove of assistance when properties of several blocks are desired. If we know the conductivity coefficient and the inside block temperature, we can find the outer surface temperature. This we find useful in designing furnaces to operate at certain inside temperatures and we wish to know what temperature we may expect on the outer surface of the block. In this form, it is also useful in computing what wall thickness, or equivalent wall thickness secured by insulation that is required to keep the heat loss down to a certain prescribed value. The third way in which the above relation is useful is that in which the conductivity and the outer surface temperature are known. In this case, we may compute the inner surface temperature, and hence arrive at an approximate value of the glass temperature at this point in the tank.

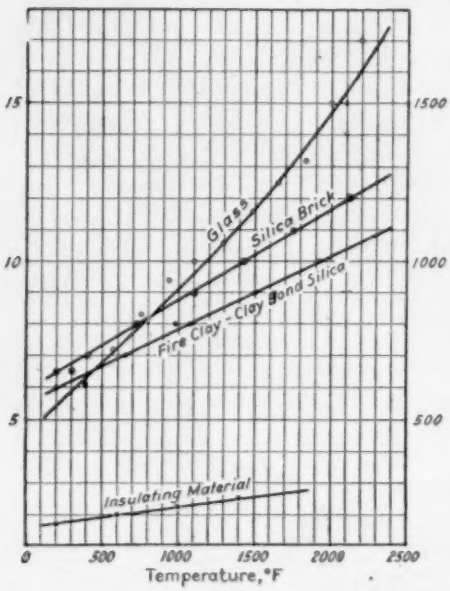

FIG. 2.—Conductivity of refractories. Conductivity, B.t.u. per sq. ft. per hr. per ° F. per in.

Before we can make these last two computations of block temperatures, however, we must have measurements of the conductivity of the block. Direct observation on this particular material seem to be lacking, although numerous workers have made measurements of the thermal conductivity of other refractory bodies. Indeed the work is so abundant and the results so numerous that one in his bewilderment knows not which value to choose for his particular case.

I do not wish to imply that these measurements are all wrong. On the contrary, they doubtless represent variations due to intensity of heat treatment, porosity, age and composition of the refractories studied together with certain differences due to methods of experimental procedure. It would certainly be worth while and at the same time afford a pleasant research to determine exactly the influence of these various factors on thermal conductivity and to further establish a method of classifying refractories by which one would be able to select the proper value for his particular case. At present perhaps we can do no better than Professor Trinks[1] has done. He gives in his book mean value curves taken from a large group of measurements of these thermal conductivities for fire clay, silica brick and insulating brick. These are shown in Fig. 2.

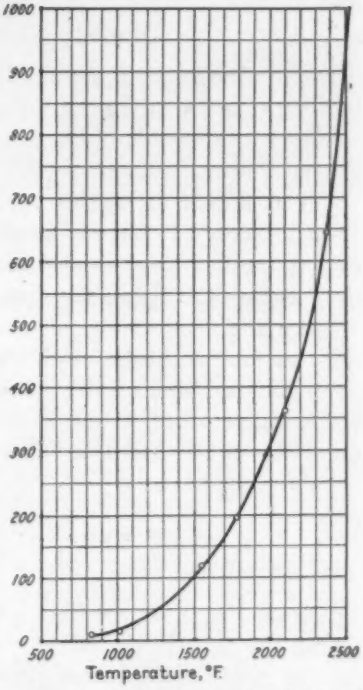

FIG. 3.—Effective conductivity of glass. Conductivity, B. t. u. per sq. ft. per hr. per ° F. per in.

Determination of Heat Conductivity of Flux Block

A few years ago the writer wishing to compute the flow of heat through a flux block wall was at a loss to know what value of thermal conductivity to use. A series of measurements were made, therefore, with a water calorimeter on a small oil-fired furnace. The furnace was blocked with 3-inch flux material and the measurements were made in the center of the bottom where the flow of heat was linear. Temperatures were measured with thermocouples of fine copper-constantin and platinum-platinum-rhodium wires. These couples were inserted in small holes drilled edgewise into the block at various known distances from its surfaces and on the surface of the block above the calorimeter. Temperature changes in the calorimeter were obtained by two copper constantin couples reading differentially. Water was supplied to the calorimeter from a constant pressure reservoir.

Results Obtained The results of this investigation are shown in Fig. 2 by way of comparison with the mean value curves given by Professor Trinks for other refractories. It is to be observed

[1] *Op. cit.*, p. 67.

that the results agree fairly well with those of silica brick and fire clay at lower temperatures. The tendency to increase with temperature appears to be more pronounced, however, in the case of the flux material. Since only one flux batch was studied, it is not to be assumed that the values for others will agree any more closely with these than do those of other refractories with one another. For the present, however, until a more exhaustive study has been made we can do no better than make our computations with these values.

Computing Inside Block Temperature

Having determined the conductivity coefficient, a single example will illustrate the use of the curves in Fig. 1 together with relation (4) above in computing the inside block temperature when the outer surface temperature is known.

Let us assume an outside surface temperature of 400°F on the face of a 12-inch block. If there is no artificial cooling of the blocks, we find from Fig. 1, the heat flow from a surface at 400°F to a room temperature of 60°F to be 1120 B.t.u. per square foot per hour.

Since the conductivity of the block varies with the temperature, we must assume an inside block temperature in order to find from Fig. 2 an approximate value of the conductivity to use. Let us then assume an inside temperature of 1800°F and then from Curve II we get a mean conductivity of 9.9 between 400 and 1800. Substituting these in relation (4) above we have

$$Q = 9.9 \frac{(1800 - 400)}{12} = 1150 \frac{\text{B.t.u.}}{\text{ft.}^2 \text{ hr.}}$$

But from Fig. 1 we see that a block at 400° outside temperature is only giving up 1120 B.t.u./ft.^{2} hr. Consequently our assumption of 1800°F for the inside block temperature is a trifle too high. A second approximation will usually result in a correct solution.

II. Heat Flow through Molten Glass

In the flow of heat through the molten glass all three processes of heat flow are in operation. Some heat is passed on from layer to layer by conduction, just as in the case of the block. Another portion is bodily carried by the movement of glass from places where the mean temperature in a vertical column is high to places where it is low; and finally a third portion is radiated from hot layers of glass to colder ones below. Since the glass is partly transparent to its own relations heat may be transmitted readily through it. This property of course depends upon the nature of the glass in question.

No data is available as to the relative magnitudes of the flow of heat in glass by these three processes. Indeed it would require careful experimentation to distinguish between them. One would be obliged to first determine the conductivity and radiation coefficient combined by experimenting in a tall narrow column of glass where convection was eliminated. Then the radiation constants would be determined by measuring the transmission and absorption factors for various temperatures. With these two observations and by measuring temperature and total heat flow in the tank we could, by difference, find the influence of convection.

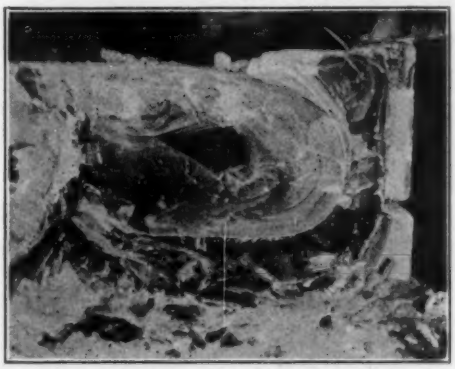

FIG. 4.

FIG. 5.

Determination of Heat Flow through Molten Glass

Some time ago the writer carried out in part the last of these three steps. This work was done in the same furnace in which conductivities of flux block were studied. The glass studied was a non-lead bulb glass. The total depth of glass was twelve inches. Measurements consisted of merely obtaining temperature gradients simultaneously in the glass and in the blocks. The ratio of these respective gradients is taken as the ratio of the effective conductivity of molten glass to that of flux block in contact with the glass. Having previously measured the latter for various temperatures, the effective conductivity of molten glass may be computed and plotted as a function of temperature. This relation is shown in the curves of Fig. 3.

Difference in Effective Conductivity of Block and Glass

It is rather striking to observe the great difference between the effective conductivity of molten glass and the conductivity of block material. Also the rapid increase in this effective conductivity is worthy of note. A glance at the curve shows us that heat flows through the molten glass at 2500°F some seventy-five times faster than it can pass through the block. If then the temperature gradient in the block is 175°F per inch, we will have in the glass near the surface, where the temperature is approximately 2500°F, only about $2^1/_2$°F change in temperature per inch depth in the glass. This difference of course, increases as the distance from the surface of the glass increases; but even at the very bottom of the pool of molten glass, the conductivity is considerably greater than it is for the block. Because of this high effective thermal conductivity of the molten glass it is possible to keep the glass in the molten state at a depth of three or even five feet by the application of heat at the surface.

FIG. 6.

Analysis of High Heat Conductivity of Glass

To say what part of this effective conductivity is due to radiation, what part to convection and what part represents a true conductivity would be mere speculation at the present time. We can, however, say with certainty that convection increases with temperature or fluidity and, in all probability, transmission to radiation decreases. The true conductivity may or may not increase with temperature, but in view of the fact that the effective conductivity which we have measured increases so rapidly with temperature, even at those temperatures where fluidity and hence convection is not great, one is fairly justified in saying that even the true thermal conductivity increases with temperature, as it does for refractory materials.

Physical Evidence of Convection in Glass

It might be well, while speaking of convection in molten glass, to present some evidence of its occurrence as well as of its magnitude. The ac-

companying photographs were made about three years ago to determine as far as possible, the movement of glass in a tank. They represent conditions in a Pyrex tank after a run of approximately fourteen months. To obtain these photographs the tank was filled and worked to a normal rate until the actual time of letting out the fires. The tank was then cooled rapidly to freeze the glass in the position occupied while working. Of course, some motion must have occurred before the glass froze. Glass moved forward into the working end to establish static equilibrium after the pull of the shops ceased. Convection also must have continued for a while. The photographs are, however, as near as can be obtained of what the glass is doing while the tank is in operation.

FIG. 7.

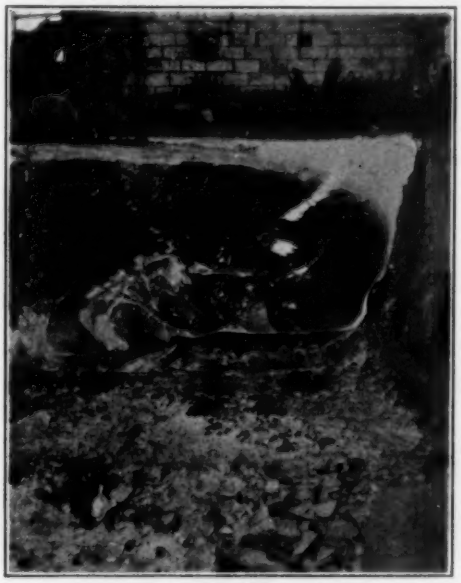

FIG. 8.

Beginning at the bridgewall and working back toward the doghouse, the glass was removed in sections of two or three feet across the tank to the full depth of the glass. As the work progressed photographs were taken.

A layer of scum consisting largely of cristobalite covered this tank and by this the convection was traced. This material, being lighter than the glass, floats on the surface and as convection from the hot center to the side walls takes place, a tendency exists to carry this scum to the walls and down to the bottom along which it returns to the central column. The combined forces of convec-

FIG. 9.

tion and gravity on this layer make it thickest at these walls and thinnest at the center. Some, however, is carried down with the convection stream in spite of gravity and affords a trace by which the force of convection is traced after the glass is frozen.

Figures 4 and 5 show the transverse convection at a point about two thirds the distance from doghouse to bridgewall. It is also to be observed that the erosion contour of the block conforms to the convection stream especially at the bottom of the tank. The surface erosion is generally affected also by other forces such as changes in surface tension of the glass caused by the solution of block material therein.

Similar effects are shown in Figs. 6 and 7. These were taken at a point about one-third the distance from doghouse to bridgewall. In Fig. 6 we see evidence of motion very near to the side block, the lower course of which is still in place.

In Figs. 8, 9, 10 and 11 we have the combined effect of transverse convection to the side walls and a longitudinal convection to the rear wall.

Figure 12 indicates that a fair temperature must have existed even on the bottom of the tank directly under the filling door to cause iron (for such is the composition of the cross) to melt and run together in one solid mass filling the cracks between these blocks.

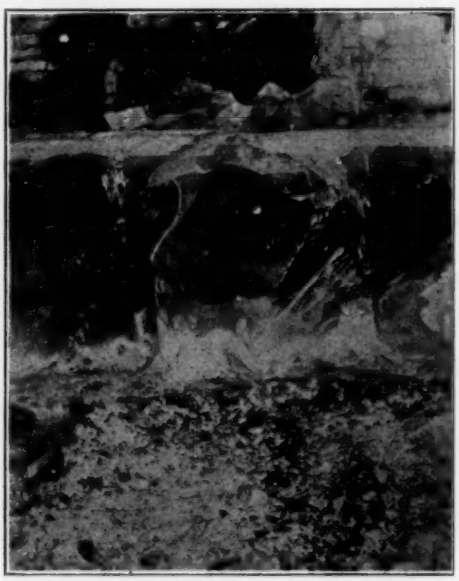

FIG. 10.

Velocity of Convection Currents in Glass

To secure some idea of the velocity of these convection currents, drops of colored glass were dropped into the center of the small tank in which conductivity experiments were being carried out. After dropping in the colored glass, the temperature was maintained for two hours, and then the fires were turned off to cool quickly. This experiment was made at temperatures of 1830°F and 2550°F. The glass was then cut out and the trace of the coloring matter observed. In the case of the lower temperature, there had resulted a movement of barely 18 inches while at the higher temperature, the coloring trails could be traced for one complete revolution to the corner of the tank down the side block across the bottom and back up the center giving in all a distance of at least six feet or a velocity of 3 feet per hour. Observations made on the movement of batch in a commercial tank melting the same bulb glass showed a surface velocity toward the cold rear corner of approximately eighteen feet per hour when the tank temperature was in the neighborhood of 2500°F. It might be emphasized in passing that this motion was in opposition to the gas current existing between ports at the time.

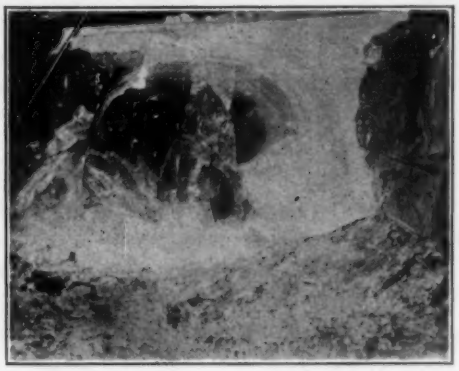

FIG. 11.

These photographs and observations are evidence of the existence of motions in molten glass that no doubt play a large part in the transfer of heat, in block erosion, and in fact on the glass quality itself. As this is primarily a discussion of heat flow, we will not consider these other effects, however interesting and important they may be.

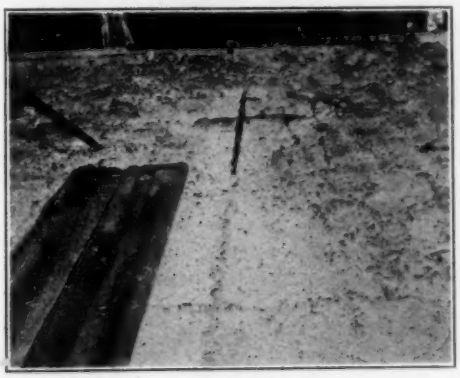

FIG. 12.

Heat Flow as Influenced by Convection

Effective conductivity of molten glass was taken to be a property inversely proportional to the temperature difference between

two points in the glass and unless convection is a perfectly definite function of this same temperature difference, we may find different effective thermal conductivities for given temperatures, depending upon the magnitude of these convection currents. This is a matter for further research to decide.

Our data at present is too meager to say whether heat transfer by convection follows an analogous law to that expressed by Lorentz and Rayleigh; for the heat loss from vertical walls cooled by air currents. According to this law heat would be supplied by convection alone to the block in proportion to the five-fourth power of the temperature difference between glass and block and in inverse proportion to the one-fourth power of the viscosity of the glass. But whether or not a definite temperature gradient is established through a given depth of glass in a tank maintained at a given surface temperature, as is assumed in the computation of effective conductivity above, it is quite possible that this gradient may be changing locally due to disturbance of temperature distribution causing new convection currents or changes in direction of old ones. These effects seem to the writer to be more plausible reasons for fluctuations observed in the glass temperature of a tank rather than changes in gas pressure as reported in the January, 1925, number of *Ceramic Industry*.

Corning Glass Works
Corning, N. Y.

THE DENSITY AND INDEX OF REFRACTION OF GLASS VERSUS ITS COMPOSITION[1]

By A. N. Finn and H. G. Thomson

ABSTRACT

A study of the available data on the relations between density, refractive index, and composition of glasses of the soda-lime series leads to the conclusion that these relations can be adequately expressed by formulas of the type $d = a(p + c)^b$, in which a, b and c are constants and d is that part of the total density of the glass due to p per cent of any constituent oxide. The results obtained for density are more satisfactory and can be applied over a much wider range than those computed by the well-known equation of Winklemann and Schott.

Introduction and Historical

The relations between the physical properties and chemical composition of any substance have always been subjects of interest and much thought has been given to the evaluation of these relations by the scientific and technical world. Glass has not been overlooked in this connection, as is evident from a study of the literature.

In connection with the work on glass which is being done at the Bureau of Standards, it seemed desirable to study the data reported by different investigators to see if they might not yield more satisfactory relations than those previously found.

Winklemann and Schott[2] published their first work on the relations between composition and physical properties of glass in 1893. Later Larsen,[3] Tillotson,[4] Peddle,[5] Baillie,[6] and English and Turner[7] added their contributions to the subject.

The conclusions reached by these investigators are in general based on the assumption that the density of glass can be regarded as a linear function of the relative amounts of its constituent oxides which is expressed by the equation $\frac{100}{D} = \frac{p_1}{d_1} + \frac{p_2}{d_2} + \frac{p_3}{d_3}$. In this equation D is the density of the glass, p_1, p_2, p_3 are the percentages of its constituent oxides, and the coefficients d_1, d_2, d_3 are the apparent densities of the corresponding oxides.

Winklemann and Schott state that the relations derived by them are only applicable to glasses very similar in composition to those from

[1] Published by permission of the Director of the United States Bureau of Standards, Department of Commerce. Presented before the Glass Division of the American Ceramic Society at Columbus, Ohio, February, 1925.

[2] *Ann. d. Phys. and Chem.*, **1893, 1894, 1897.**

[3] *Am. J. Sci.*, **28,** 263 (1909).

[4] *J. Ind. and Eng. Chem.*, **3,** 897 (1911); **4,** 246 (1912).

[5] *Jour. Soc. Glass Tech.*, **1920, 1921, 1922, 1923.**

[6] *Jour. Soc. Chem. Ind.*, **40,** 141 (1921).

[7] *Jour. Soc. Glass Tech.*, **1920, 1921, 1922, 1923.**

which the values of d were obtained and that for glasses of different composition the relations are not so satisfactory. Although the others do not make such a statement, a study of their results leads to the same conclusion, and the values they report for apparent densities, or "factors" as they are called, vary with the types of glass from which they were derived. The factors recommended by various investigators are given in Table I.

TABLE I

GENERAL EQUATION AND FACTORS FOR SEVERAL OXIDES RECOMMENDED BY SCHOTT (S), TILLOTSON (T), BAILLIE (B), AND ENGLISH AND TURNER (E. & T.)

$$\frac{100}{D} = \frac{p_1}{d_1} + \frac{p_2}{d_2} + \frac{p_3}{d_3} + \ldots\ldots$$

	S	T	B	E. & T.
SiO_2	2.3	2.30	2.24	2.20
Na_2O	2.6	2.60	3.20	3.47
CaO	3.3	4.10	4.30	5.00
MgO	3.8	4.00	3.25	3.38
Al_2O_3	4.1	2.75	2.75	2.75

Peddle did not derive a series of factors, but states: "The assumption that the density of glass can be calculated from the densities of the constituent oxides is in error, and the equation of Winklemann and Schott for the calculation of density is of no use where 'extreme' glasses are concerned, that is, glasses containing an abnormal amount of any constituent oxide."[1]

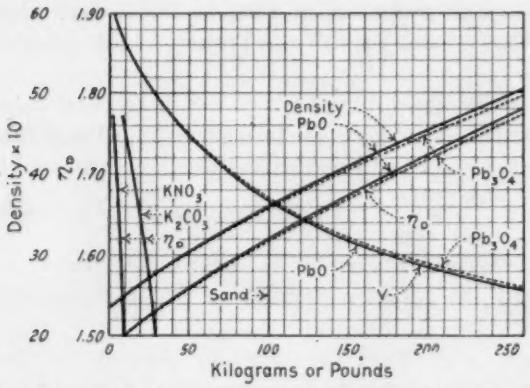

FIG. 1.—Batch composition diagram for the series of ordinary flint glasses. The diagram is prepared on the basis of sand 100. From the diagram the approximate batch composition for any flint glass of given refractive index, n_D, or V-value, or density, d, can be read off directly.

General

If the changes in the density of glasses of different composition are plotted against changes in composition on rectangular coördinate paper, the graph is almost invariably a curve and not a straight line which would be required by the Schott equation. This is well illustrated by the diagram prepared by F. E. Wright,[2] by means of which

[1] *J. Soc. Glass Tech.*, **4**, 8 (1920).

[2] "The Manufacture of Optical Glass and Optical Systems," p. 101.

he shows the relations between composition, density, index of refraction, and dispersion of optical glasses of the lead series (Fig. 1).

Since these curves and other available data show gradual changes in the properties of glass with small variations in composition and do not, in any range, show a rapid change in slope which might be expected if there were changes in molecular constitution, it is safe to assume, for the purpose of this work, that changes in the density of glass are continuous functions of the relative amounts of its constituent oxides.

This assumption might lead to the conclusion that glass is a homogeneous mixture of its constituent oxides and devoid of molecular combination. Such a conclusion is not necessarily true, as it may safely be stated that the observed density and also index of refraction are the results of averages of mixtures of compounds which have not been allowed to assemble in groups of sufficient size to permit their detection or identification.

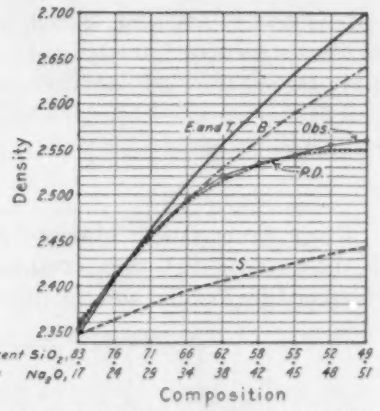

FIG. 2.—Comparison of observed densities (obs.) of silica-soda glasses and densities computed by English and Turner (E. and T.), Baillie (B), Schott (S) factors, and the "partial density" method (P. D.).

Silica and Soda

The work reported in this paper is based largely on the results obtained by Peddle,[1] who made a series of silica-soda glasses varying in composition from approximately 83% silica and 17% soda to 50% each of silica and soda. The density of these glasses varied from 2.353 to 2.560.

Assuming that the change in density is a function of the change in the percentages of silica and soda, it was found that the relation could be quite accurately expressed by an equation of the form $d = a(p + c)^b$ in which d is the "partial density" or that part of the density of the glass that might be attributed to either of the constituent oxides, p is the percentage of that oxide and a, b and c are empirical constants which have the following values:

Oxide	a	b	c
SiO_2.....	0.3325	0.4463	—30
Na_2O.....	0.01869	1.081	0

The density, D, of the nine silica-soda glasses reported by Peddle is the

[1] *J. Soc. Glass Tech.*, **4**, 6 (1920).

sum of the partial densities of the silica and soda and may be computed from the equation

$$D = 0.3325\,(p - 30)^{0.4468} + 0.01869\,(p)^{1.081}$$

with a maximum difference of less than 0.25% (or 0.006 actual density) between the computed and observed values except for the 50-50 glass, in which case the difference is 0.43% (0.011 actual density). Figure 2 shows the observed values, which are represented by circles, the values obtained by computing the densities of this series of glasses by the "partial density" method and by the Schott equation using the factors recommended by English and Turner, Baillie, and Schott, and also the composition of the glasses considered.

It is evident from Fig. 2 that Schott's statement regarding "similarity" of glasses is correct, for although the differences are not great in the high silica region, they become much greater as the silica content decreases and reach maxima of —4.5% (—0.117) and +5.5% (+0.141) when the silica-soda ratio is 49:51.

Lime

Using the equations obtained for silica and soda, the partial densities of these constituents were computed for the twelve silica-soda-lime glasses discussed by Peddle[1] and the difference between the sum of these and the observed density of the glass was considered the partial density due to lime. These values are given approximately by the equation

$$d = 0.03365\,(p)^{0.9887}$$

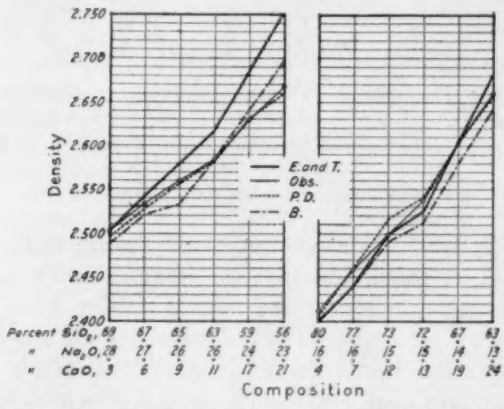

FIG. 3.—Comparison of observed densities (obs.), of silica-soda-lime glasses and densities computed by English and Turner (E. and T.), and Baillie (B) factors, and the "partial density" method (P. D.).

The maximum difference between the observed density of any of these glasses and the density obtained by adding the partial densities computed from the equations for silica, soda and lime was 0.72%. Substitution of the Baillie and English and Turner factors in the Schott equation gave maximum differences of 1.0% and 3.3%, respectively. These results are shown in Fig. 3.

[1] *Jour. Soc. Glass Tech.*, **4**, 76 (1920).

In applying these equations to a series of seventeen soda-lime glasses reported by English and Turner,[1] satisfactory agreement was not obtained between the computed and observed densities. Although the maximum difference was 0.72%, as it was in the case of the Peddle glasses of this type, the other values did not agree as well as in the previous case. However, by proceeding with the English and Turner glasses as in the case of the Peddle glasses, somewhat different constants were obtained for the lime equation as indicated below:

	Constants for lime equation		
Glass made by	a	b	c
English and Turner..	0.02813	1.035	+0.2
Peddle.....	0.03365	0.9887	0.0

The use of this modified equation for the partial density of lime gave a maximum variation of 0.28% (0.007) as compared with 0.9% (0.023) obtained by the English and Turner factors, and again this relatively large difference was obtained when the composition changed materially. (The silica content changed from 74% to 66% with a corresponding increase of the lime.)

The need for different constants in the lime equation, which are required to satisfy the data, may be due to several uncertain conditions among which may be mentioned (1) the actual compositions of the glasses considered, (2) the degree of annealing,[2] and (3) variations in temperature at which the densities were determined,[3] assuming that all samples were free from bubbles or seeds.

The compositions of the glasses reported by Peddle could only be obtained from batch compositions as no analyses were reported, and certainly some change will always be produced by volatilization of certain constituents and by solution of the clay from which the melting pots were made. The compositions of the English and Turner glasses were obtained by chemical analysis and hence are probably more reliable.

Peddle does not state the degree of annealing for his glasses nor the temperature at which densities were determined, while English and Turner emphasize the necessity of using only well annealed glass and state that the densities of their glasses were determined at 20°C. However, Peddles' glasses were cooled in the melting furnace and it is not thought that they were highly strained, although they were probably not well annealed.

[1] *Jour. Soc. Glass Tech.*, **3**, 126, 227 (1919); **4**, 127 (1920). The composition of these glasses varied as follows: silica, 66–75%, soda 11–25%, lime 0.2–18%.

[2] Tool and Eichlin have shown that in some glasses the density may be decreased as much as 1% by rapid cooling from the maximum annealing temperature (*J. Opt. Soc. of Am.*, **8** [3], 437 (1924).

[3] Neglecting the thermal expansion of glass, a glass whose density at 4°C is 2.50 will have an apparent density of 2.5025 at 15°C and 2.5050 at 20°C or a difference of 0.1% between 15° and 20°C.

Magnesia and Alumina

Following the same method of computation as used in obtaining the values of a, b and c in the partial density equation for lime, and using the data on the soda-magnesia and soda-alumina glasses made by English and Turner[1] the following constants were obtained for the partial density equations of magnesia and alumina:

Oxide	a	b	c
MgO	0.3017	0.9262	0
Al_2O_3	0.00675	1.3571	+3

Using these constants for determining the partial density of magnesia, the maximum difference between the computed and observed densities of the soda-magnesia glasses is 0.2% (0.005), whereas the English and Turner factors give 0.66% (0.016) and the Baillie factors give 0.25% (0.006), which is a better agreement for the "factor" method than was obtained for the soda-silica or soda-lime-silica glasses.

The constants for determining the partial density of alumina are not very satisfactory and although they will be briefly referred to again in this paper, a more complete discussion will be presented in a future paper on this subject.

Index of Refraction

A method of reasoning similar to that used in considering the effects of changes in composition on density was applied to index of refraction. This led to a similar series of equations in which the constants for the "partial index of refraction" (n_d) due to silica, soda and lime are as follows:

Oxide	a	b	c
SiO_2	0.03875	0.8063	−10
Na_2O	0.01406	1.0193	0
CaO	0.01332	1.069	+ 1

Using these constants in the equations $N_d = n_{d_1} + n_{d_2} + n_{d_3} + \ldots\ldots$ and $(n_d)_x = a(p_x + c)^b$, the computed indices of refraction of the soda-silica glasses varied less than 0.001 from the observed indices if the soda did not exceed 30%, and the computed indices of five soda-lime glasses[2] made and analyzed at the Bureau of Standards varied less than 0.005 from the observed values. These values are not as good as those obtained by Tillotson,[3] who determined K (specific refractive power) in the Lorentz equation, using values of d obtained by substituting his own factors for apparent density in the Schott equation.

[1] *Jour. Soc. Glass Tech.*, **4**, 155 (1920); **5**, 277 (1921).

[2] Approximate composition of these glasses was: silica 75%, soda 13% and lime 12%.

[3] *Jour. Ind. and Eng. Chem.*, **4**, 246 (1912).

Results Obtained by Extrapolation

It is exceedingly interesting to note the results obtained by computing the densities and indices of refraction at 100% for the oxides discussed in this paper (see Tables II and III). The silica equations at 100% (in other words, pure silica) give a density of 2.214 and an index of refraction (N_d) of 1.4587, an excellent agreement with the observed values for fused silica which are, according to Larsen, 2.213 and 1.4590.

The lime equations at 100% give a density of 3.195–3.310 and an index of refraction of 1.8516. The reported densities of pure lime vary from 3.08 to 3.30 and the index of refraction varies from 1.725–1.83. In this connection attention is directed to the fact that although the computed index

TABLE II

"PARTIAL DENSITY" EQUATIONS AND VALUES OF a, b AND c FOR SEVERAL OXIDES. ALSO, COMPUTED DENSITY FOR 100% OF EACH OXIDE AND THE OBSERVED DENSITY

$$D = d_1 + d_2 + d_3 + \ldots\ldots$$
$$d_x = a(p + c)^b$$

	a	b	c	100% Comp.	100% Obs.
SiO_2	0.33250	0.4463	—30.0	2.214	2.213
Na_2O	0.01869	1.0810	0	2.715	2.550
CaO[1]	0.03365	0.9887	0	3.310	3.08–3.33
CaO[2]	0.02813	1.0350	+0.2	3.195	3.08–3.33
MgO	0.30170	0.9262	0	2.148	3.47–3.64
Al_2O_3	0.00675	1.3571	+3.0	3.640	3.850

TABLE III

EQUATIONS AND CONSTANTS FOR DETERMINING INDEX OF REFRACTION (N_d) OF SILICA-SODA-LIME GLASSES. ALSO, COMPUTED INDEX FOR 100% OF EACH OXIDE AND OBSERVED INDEX

$$N_d = (n_d)_1 + (n_d)_2 + (n_d)_3 + \ldots\ldots$$
$$(n_d)_x = a(p + c)^b$$

	a	b	c	100% Comp.	100% Obs.
SiO_2	0.03875	0.8063	—10	1.4587	1.4585
Na_2O	0.01406	1.0193	0	1.5369	
CaO	0.01332	1.0690	+1	1.8516	1.725–1.83

of refraction of lime is higher than that given for crystallized lime, this is consistent with the fact that in those crystalline minerals which contain high percentages of lime and can also be obtained in the form of glass, the index of refraction of the glass is higher than that of the crystal and since, in general, an increase in refractive index is accompanied by an increase in density, it follows that the density of similar lime compounds might be higher in the glass than in the crystal. This might be interpreted as an indication that lime undergoes a molecular contraction when

[1] From SiO_2–Na_2O–CaO glasses reported by Peddle.

[2] From SiO_2–Na_2O–CaO glasses reported by English & Turner.

present in glass, but it may also indicate that lime in a glass produces a greater contraction or condensation of one or more of the other constituent oxides which, by the method of computation used, would not be attributed to those oxides but would be attributed entirely to the lime and hence produce relatively higher values for it.

The value obtained for the density of magnesia at 100% is 2.148. This is much lower than any reported values for the density of pure magnesia[1] which vary from 3.47 to 3.64, but this low computed value is consistent with the fact that the magnesia glasses have lower densities than glasses in which it is replaced by lime.

The value computed for pure alumina, 3. 4, indicates that it should produce a greater increase in the density of a glass than either lime or magnesia, but, as a matter of fact, its effect is similar to magnesia, *i. e.*, it produces a glass of lower density than one containing a corresponding amount of lime.

It must be borne in mind, however, that the range of compositions on which these conclusions are based varied considerably. The percentage of silica varied from 50–85%, soda 15–50%, lime 3–24%, magnesia 1–10%, alumina 3–13%, and the extrapolation of values from 10% or 20% to 100% may not be justified and this the more because the actual composition of all the glasses considered is not definitely known and the validity of the initial assumption on which the arguments are based has not been definitely established.

Conclusions

In conclusion it may be stated that the density of the glasses of the silica-soda-lime series and also some others may be computed with greater accuracy and over a wider range of compositions than by any previously reported methods.

The relations deduced are expressed by the equations

$$D = d_1 + d_2 + d_3 \text{ and}$$
$$d_x = a(p + c)^b$$

in which D is the density of the glass, d_1, d_2, d_3 are the partial densities due to the constituent oxides, p is the percentage of the corresponding oxides and a, b and c are constants which differ for each oxide. The values of a, b and c for silica soda, lime, magnesia and alumina are given in Table II.

Similar relations between the index of refraction and composition of the same glasses have been observed, but the values of a, b and c which are given in Table III for the partial index of refraction equations have not as yet been satisfactorily established.

[1] More or less crystallized.

The accuracy of the results obtained by the method described in this paper justifies the prediction that tables can eventually be prepared from which it will be possible to determine the composition of a glass from its density and index of refraction. This will furnish a very satisfactory method for controlling the uniformity of composition of glasses without the delay incident to chemical analysis. Also, it will be possible to compute with much greater accuracy than is now possible the composition of a glass that will be required to give a specified index of refraction, which is a matter of extreme importance to the manufacturer of optical glass and to the designer of optical instruments.

NOTES ON THE OPERATION OF DIRECT FIRE TUNNEL KILNS[1]

By V. J. Roehm

ABSTRACT

The successful application of the direct fire car tunnel type kiln in firing of semi-vitreous chinaware is described. The bisque kiln firing to cone 9 one-half down is 332 feet 11 inches long, the placing height at middle of crown being 6 feet and the placing width 5 feet 1 inch. The glost kiln operating at cone 5 has the same placing height and width as the bisque but the length is 301 feet 1 inch long. The ware is placed in saggers as formerly. Natural gas is used as fuel and is supplied to kiln through Maxon Premix burners; an auxiliary fuel oil system can be used in case the gas is not available.

After a year's operation some of the important conclusions drawn are as follows:

1. The heat distribution is not ideal.
2. There is no appreciable difference in labor cost at this plant than in the older ones.
3. There is a considerable saving in fuel.
4. The sagger loss is much less than in the older type plants.
5. The direct fire tunnel kiln has proven successful from the commercial standpoint in manufacturing semi-vitreous china.

The two Harrop car tunnel direct fire kilns, one for bisque and the other for glost, were first producing ware at the new No. 6 plant of the Homer-Laughlin China Company, Newell, W. Va., the latter part of February, 1924. These kilns are firing only certain items of whiteware to meet a particular trade although they will fire satisfactorily all sizes and shapes of this type of ceramic ware.

The Equipment

Size of Kilns Both kilns are identical in every respect except in length and number of furnaces. The kilns are of the side vestibule type, the bisque being 332 feet 11 inches long from outside of vestibule to outside of vestibule and will accommodate 53 cars. The glost kiln is 301 feet 11 inches long from outside of vestibule to outside of vestibule, having accommodations for 48 cars. The cars are 6 feet 1 inch long, the placing width is 5 feet 1 inch and the placing height, excluding the height of setter blocks, being approximately 6 feet at the middle of the crown.

Pusher A hydraulic ram manufactured by the Oil Gear Co., Milwaukee, Wis., pushes the cars through the kiln at a constant speed. Under full load the pressure against the ram on the bisque is about 550 pounds while that of the glost varies from 340 to 380 pounds.

Temperature Control The temperatures under the cars and at 12 different positions along the length of the kiln, and at furnaces, Nos. 7 and 8 of the bisque, are gotten by means of 8 noble and 9 base metal thermocouples. On the glost 9 noble and 7 base metal couples

[1] Recd. Feb. 14, 1925.

are employed to measure the temperatures under the cars, the last four furnaces, and at 11 different positions along the length of the kiln. The junction boxes are provided with temperature compensation coils. All terminals are located in a central control house situated between the discharge end of the bisque and the charging end of the glost kiln. The Leeds-Northrup potentiometer is used, each kiln having an indicating type which gives the temperature at any one couple and a three point recorder which records the three maximum crown temperatures. After eleven months of continuous service both types have given us complete satisfaction.

Furnaces

Along the firing zone of the bisque kiln there are ten furnaces, five on each side. Each furnace is equipped with a Maxon Premix combination gas and oil burner. The glost kiln is equipped like the bisque with the exception, that there are eight furnaces, four on each side. When firing on a 90-minute schedule only eight furnaces are used on the bisque. Any faster schedule requires ten furnaces.

Fuel Oil System

When oil is used for firing, the oil is first pumped from the storage tanks to the kiln shed level, at 20 pounds pressure. It is then pumped by means of a Viking pump, through a Lunkenheimer regulator, which keeps the pressure constant at about 45 pounds, then through a Powers heater, which pre-heats the oil to about 140°F after which it goes to the burners.

Gas Used

So far the kilns have been fired almost continuously with natural gas, the pressure of the gas being kept within the limits of $4^1/_2$ and $4^3/_4$ ounces by means of an inside regulator for the glost and at about $4^1/_4$ ounces for the bisque.

Electric Power Required

The electric current is 220 volts, 2 phase, 60 cycle alternating, and the electric power required for the bisque when firing on a 90-minute schedule with natural gas includes a 10 h. p. draft fan motor, a 10 h. p. pressure fan motor, eight $^1/_2$-h. p. burner motors and one $^3/_4$-h. p. pusher motor, a total of $24^3/_4$ h. p. The same amount of electric power is required for the glost kiln.

Operation of Bisque Kiln

Bisque Kiln Car Schedule

The bisque kiln has been run on a 120, 115, 110, 105, 100, 95, 90, 85, 80, 75 and 70-minute schedules and good ware has been produced on all of them. The majority of the time the kiln has been run on a 90-minute schedule, the maximum temperature being 2060°F in crown. The time in the firing zone on a 90-minute schedule is 12 hours and 36 minutes. This brings cone 9 about $^3/_4$ down. Each bisque car has a capacity of 103

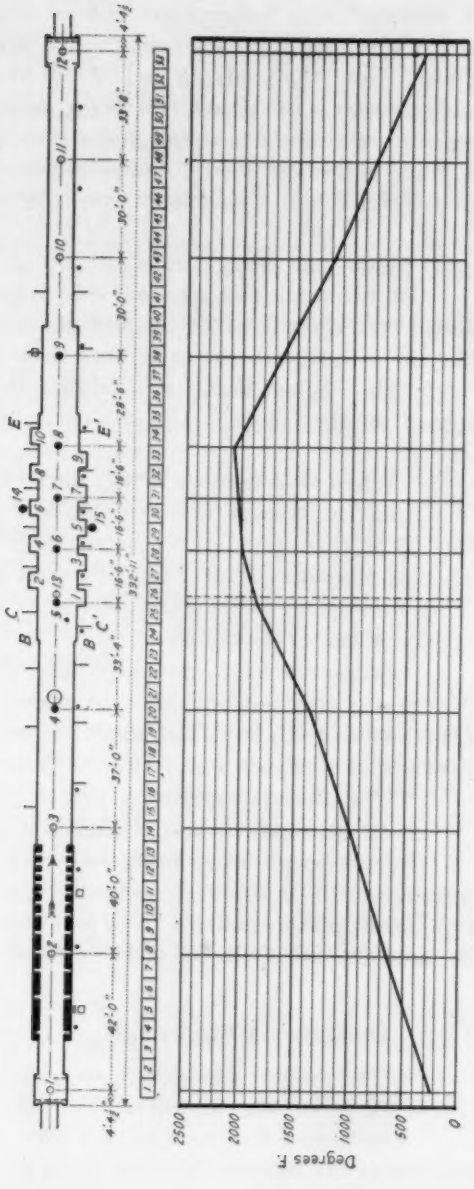

FIG. 1.—Bisque temperature record. 80-minute schedule at cone 9½.

saggers or 300 dozens of ware. From this it appears that 16 cars are equal to an 18-foot periodic kiln.

Bisque Kiln Fuel Consumption

On a 90-minute schedule the average gas consumption is 120,000 cu. ft. in 24 hours. An 18-foot periodic kiln requires on an average of 325,000 cu. ft. to fire off, so from these figures saving amounts to approximately 63%.

Draft Regulation

Our experience has shown that the drafts should be so regulated that the neutral point (where the negative pressure balances the positive pressure) is between furnaces Nos. 1 and 2, and the draft gage at position "*C'''*" (see Fig. 1), shows 0.040 inches of negative pressure. We have found that more uniform firing is obtained when there is a positive pressure down as far as No. 2 furnace.

Atmosphere Control

The kiln gas has been drawn from the kiln at position *C'* (see Fig. 1) and the CO_2 and O_2 content determined. Below are given the tabulated results together with other data.

TABLE I

Date	Time	Per cent CO_2	Per cent O_2	Schedule Min.	Exhaust gas temp. °F	Gas consumption, cu. ft.
10/27/24	1:25 p.m.	5.1	12.3	90	410	136,500
10/28/24	9:10 a.m.	4.6	13.7	90	400	136,000
12/17/24	8:30 a.m.	5.8	14.2	90	490	131,000
12/19/24	10:25 a.m.	6.0	11.8	90	490	130,000
12/22/24	10:20 a.m.	5.4	13.0	100	480	113,000
12/23/24	9:15 a.m.	4.5	15.1	100	475	119,000
1/ 5/25	9:05 a.m.	4.2	13.6	100	450	117,700
1/ 6/25	8:45 a.m.	4.5	12.5	100	400	114,100
1/ 7/25	8:50 a.m.	4.8	12.1	90	400	115,600
1/ 8/25	10:30 a.m.	5.6	12.3	90	430	114,600
1/ 9/25	9:00 a.m.	5.0	11.4	90	400	113,800
1/12/25	9:00 a.m.	4.8	13.6	90	395	112,000

Av. CO_2 = 5.04% Av. O_2 = 13.0% Av. temp. 435°F Av. gas consumption, 121,000 cu. ft.

Temperature Control and Distribution

Figures 4 and 5 show the temperature variations along the length of kiln obtained by means of an optical pyrometer focused upon the saggers at the middle part of car as to its height. Optical pyrometer readings were also taken at the top, middle and bottom of kiln at positions marked "*C*," "*C'*," "*E*" and "*E'''*" (see Fig. 1).

The temperature variations are shown in Figs. 6 and 7. From the results one can see that the heat distribution is not perfect. This is in all probability due to the high velocity of the gas which pushes ahead at the top, while there is a stratum of cooler gases along the car tops. The mean velocity through the bisque kiln section at *C* (see Fig. 1) is 13.3 feet per second. But it is evident that in the more open positions it must be greater and in the tighter, slower.

The bisque kiln is much slower to respond when any marked change is made than the glost. The firemen are able to keep the temperatures more constant than that of the glost, but when they do get off it takes a much longer time to bring them back where they should be. The diminished fluctuations in the maximum crown temperatures of the bisque over those in the glost, I believe, can be attributed to the following reasons:

1. The cars travel through the kiln at a much slower rate.
2. The sagger settings are nearly uniform.
3. A smaller amount of air is required to cool the ware, therefore, the velocity of the gas is less.

z	y	x
8.81%	8.76%	9.17%
8.51%	8.26%	8.61%
7.79%	7.71%	8.04%
6.92%	7.13%	7.20%
6.97%	7.37%	7.34%
6.62%	6.42%	7.56%
6.19%	6.02%	7.14%
6.71%	7.23%	7.53%
6.77%	8.30%	8.46%

Absorption of ware from top to bottom in bungs *x*, *y* and *z*.

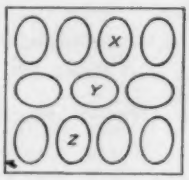

FIG. 2.—Top view of car showing bungs from which absorption trials are taken.

For the 90-minute bisque kiln schedule the time of preheating is 36 hours 47 minutes, the time within the firing zone 12 hours 36 minutes and the cooling time is 29 hours 15 minutes.

The effective heat distribution is best shown by the absorption of the ware from different parts of the car. In the illustration of Fig. 2, there is indicated the position of the different saggers and the absorption of ware contained in each. From this it appears that the heat effect in general is very satisfactory and much better than in the periodic kilns.

Operation of Glost Kiln

Capacity of Glost Kiln

Each glost car has an average capacity of 75 saggers or 130 dozens ware. Figuring on the dozen basis eighteen cars are equal to a 16 ft. 6 in. periodic kiln. The kiln has been operated on a 60, 55, 50, 45 and 40-minute schedule according to the needed production. The schedule of 45 minutes has been followed the greater part of the time since the installation.

Fuel Consumption

For this 45-minute schedule the average daily consumption of gas for 24 hours is 114,000 cu. ft. Figuring the average gas consumption of a 16 ft. 6 in. periodic glost kiln at 225,000 cu. ft., the fuel saving is approximately 71.0%.

Time Schedule

The maximum temperature on a 45-minute schedule is 2000°F in the crown and at this tem-

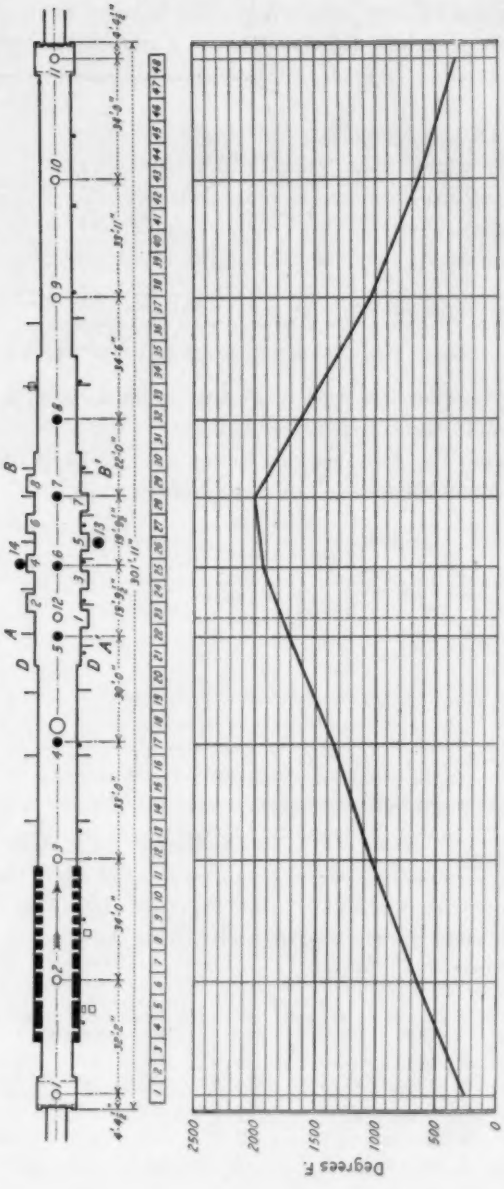

FIG. 3.—Glost temperature record. 45-minute schedule. Cone 5¾.

perature we get cone 5 about three-quarters down. It has been our experience that the 45-minute schedule is the fastest we can operate and still get a large percentage of first class ware. For several weeks the kiln was run on a 40-minute schedule the result being a noticeable amount of dull

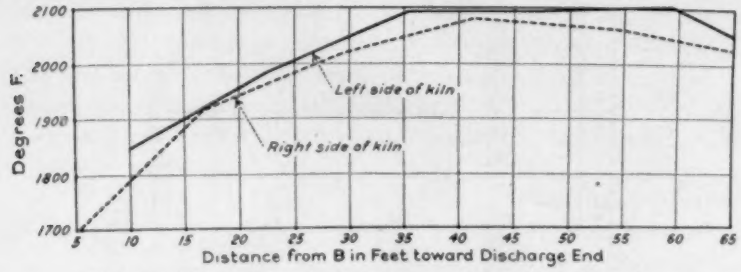

FIG. 4.—Bisque kiln. 90-minute schedule. (See Fig. 1.).

and easy ware. Another loss which became quite large was that of the saggers due to a more rapid heating and cooling. On a slow schedule the kiln is more flexible, the kiln firemen being able to keep more constant temperature and therefore a more uniform product results.

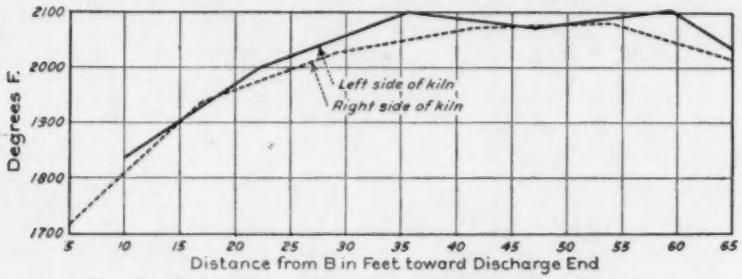

FIG. 5.—Bisque kiln. 80-minute schedule. (See Fig. 1.).

Atmosphere Control in Glost Kiln

Some data was gathered as to the CO_2 and O_2 content of the kiln gases as they left the firing zone at position A' (see Fig. 3). Below are given some of the figures in tabulated form together with other data:

TABLE II

Date	Time	Per cent CO_2	Per cent O_2	Schedule Min.	Exhaust gas temp., °F	Gas consumption, Cu. ft.
5/17/24	8:40 a.m.	3.4	14.6	40	249	135,500
5/20/24	9:15 a.m.	3.6	14.4	40	261	146,000
5/21/24	12:00 p.m.	2.8	15.5	40	257	148,800
5/27/24	8:25 a.m.	4.1	12.7	40	253	138,000
5/30/24	7:40 a.m.	3.4	14.0	40	248	138,000
6/ 6/24	8:50 a.m.	2.3	16.5	45	244	134,000
6/10/24	8:45 a.m.	2.8	15.0	45	274	124,800
6/18/24	8:50 a.m.	2.8	14.8	45	271	118,000
6/26/24	1:15 p.m.	3.5	14.1	45	281	120,280

7/ 1/24	9:00 a.m.	3.2	14.4	55	302	119,300
7/ 2/24	9:05 a.m.	3.0	14.0	50	295	121,000
7/ 3/24	8:45 a.m.	3.2	11.8	50	267	120,000
7/ 6/24	8:30 a.m.	4.0	13.0	45	263	125,000

Av. CO_2 = 3.24% Av. O_2 = 14.06% Av. temp. 266°F Av. gas consumption, 122,000 cu. ft.

Draft Control in Glost Kiln

As to draft conditions we have found that the most satisfactory results are obtained when the neutral point is between furnaces 3 and 4, and the draft gage at A' (see Fig. 3) registers 0.055 inches negative draft. The temperatures of furnaces 5, 6, 7 and 8 are very important, and the firemen

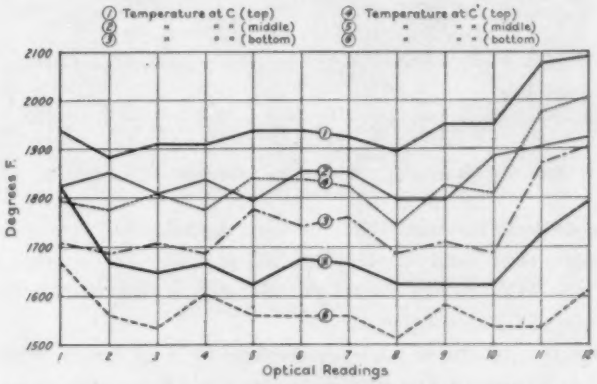

FIG. 6.—Temperature variations at C and C' (see Fig. 1) as found by optical pyrometer.

are warned to keep them at a minimum, and still hold the maximum crown temperatures. Invariably when the crown temperatures are up and the furnace temperature is 10°F above what it should be, we get some blis-

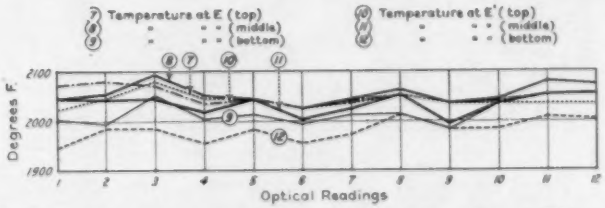

FIG. 7.—Temperature variations of bisque kiln at E and E' (see Fig. 1) as found by optical pyrometer.

tered and twisted ware in those saggers which pass close to the furnace mouths. This is also true when one has a slight flame in the combustion chamber. For this reason enough air is premixed with the gas till the flame disappears.

Temperature Control in Glost Kiln

Figures 8 and 9 show the results of optical pyrometer readings taken along the kiln representing the temperature of the outside sagger at the middle part of car as to its height. Optical pyrometer readings were also taken at the top, middle and bottom of kiln at points marked A, A', B and B' (see Fig. 3). The results of these readings are shown on Figs. 10 and 11.

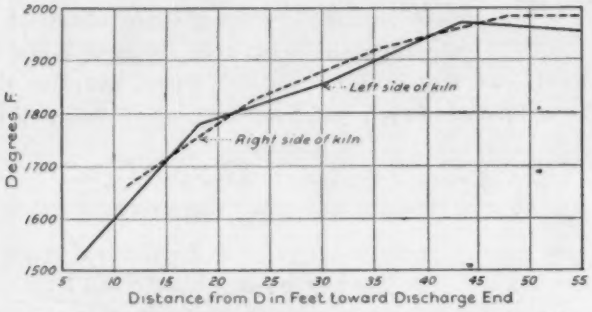

FIG. 8.—Glost kiln. 45-minute schedule. (See Fig. 3.)

From these curves it is seen that the heat distribution is not an ideal one and we believe that some of the streakiness is due to the high velocity of the gas in the kiln (about 18 ft. per second) which causes the gases to follow the line of least resistance.

The crown temperatures vary as much as 10°F at times, within 45 minutes. This is due in all probability to the variation in the sagger settings.

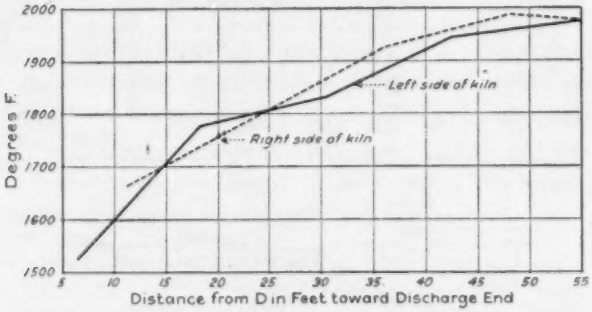

FIG. 9.—Glost kiln. 55-minute schedule. (See Fig. 3.)

In some cases the space between bungs is quite open and it does not extend very near to the crown of the kiln. In others the bungs are very tight, and are bunged to the maximum height. In the first case when a car so set comes into the hot zone the crown temperature begins to drop. On the other hand as long as there is a string of loose and low set cars a constant temperature can be maintained, but if a tight car with saggers bunged to

the maximum height comes in between the loose set cars the crown temperatures immediately begin to rise. Endeavors have been made to keep the settings of the cars as uniform as possible, but since there are so many different sizes and shapes of saggers, it is really a big problem.

On a 45-minute schedule the time of preheating the glost ware is 16 hours 12 minutes, the time within the firing zone is 4 hours 54 minutes and the cooling time is 14 hours and 24 minutes.

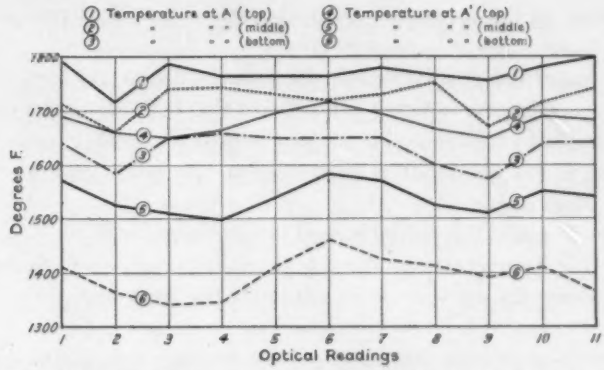

FIG. 10.—Temperature variations of glost kiln at *A* and *A'* (see Fig. 3) as found by optical pyrometer.

Economies

The two kilns are operated in three shifts of eight hours each. A crew is composed of a fireman and two helpers. The placing and drawing of the kilns are done on a day wage scale, the cost of placing being more than that of the older plants, while the drawing costs a little less. The average cost of both is a trifle higher than for the old style plants. The number of

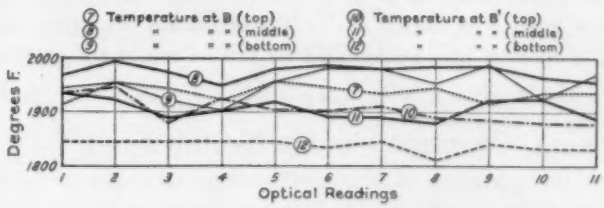

FIG. 11.—Temperature variations af glost kiln at *B* and *B'* (see Fig. 3) as found by optical pyrometer.

thirds produced in this plant are about 15% below that of the other plants. The sagger loss for both the bisque and glost kilns is approximately 35% lower than that of the older plants. In the eleven months of operation one wreck has occurred in the glost kiln, probably due to a faulty sagger; at this time the kiln was shut down for only six hours and the total time lost was not more than ten hours.

Summary

1. A 45-minute schedule on the glost is the fastest which is feasible without decreasing the quality of the ware. The greater the speed the more temperature variation will occur.

2. Minimum furnace temperatures on the glost are necessary to prevent excessive warping and blistering and they should approach the kiln crown temperatures as closely as possible.

3. A flame in the furnaces produces warped and blistered ware in the glost.

4. The faster the glost schedule the greater the sagger loss.

5. Under ordinary working conditions the heat distribution of both kilns is somewhat variable and is subject to improvement.

6. There is no appreciable difference in the labor cost at this plant than at the older ones.

7. There is a decided saving in fuel: approximately 67%.

8. The car temperatures should be maintained as high as possible without injuring the cars, so as to minimize the heat flow through the car platforms.

9. Further improvements should look toward the partial elimination of the flow of cooler air from the discharge end along the car platforms toward the firing zone. Likewise, the speeding ahead of the heated air under the crown both in the cooling and the heating-up section should be reduced as much as possible.

10. The regulation of the pusher speed is very important and it would be very desirable to work out an automatic regulator which would keep the speed reasonably constant.

11. The direct fire tunnel kilns have proven successful from the commercial standpoint, in firing of semi-vitreous table ware.

The writer wishes to thank A. V. Bleininger for his many helpful suggestions in preparing this paper and to J. P. Connor for getting much of the data.

THE HOMER-LAUGHLIN CHINA CO.
NEWELL, W. VA.

CERAMIC DRYING AND DRIERS[1]

With Special Reference to the Advantage of Controlled Temperature, Humidity and Air Movement

By A. E. Stacey, Jr.,[2] and H. B. Matzen[3]

Abstract

Construction for and principle of humidity drying.

Introduction

The art of successful ceramic drying is coming to be more and more appreciated as an "air processing" rather than a mere removal of moisture.

The law governing the rate of evaporation stated by Carrier, Lewis, Himus, Hinckley, Fisher and others, is: "The rate of evaporation varies with the velocity of the air in contact with the wet surfaces and also is dependent on the difference in the temperature between the wet and dry bulb temperatures of the air." This last is known as the wet bulb depression. This is approximately constant for any relative humidity at different dry bulb temperatures.

As it is essential to control the rate of drying, a drier, to be entirely successful, must provide a uniform brisk circulation of air over all parts of the material, and be so designed that the temperature and relative humidity are controllable, either manually or automatically.

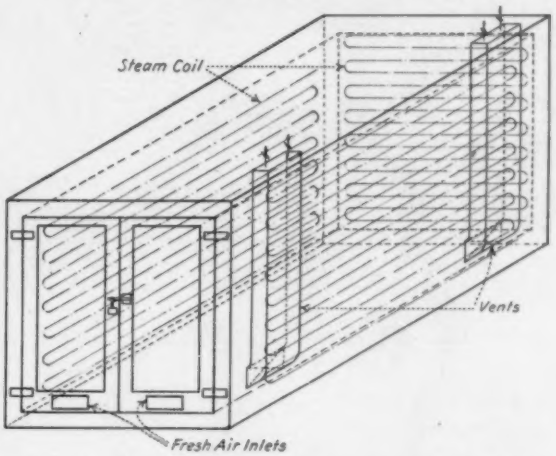

Fig. 1.—Early type of drier using gravity air circulation.

Types of Driers and Air Circulation

Driers are divided into two general types, as to method of air circulation, one depending on gravity and the other on mechanical means.

Figure 1 illustrates one of the earlier examples of driers, which depend on gravity for air circulation. The air first comes into contact with the hot heating surfaces and then with the material. As it passes through the material, evaporating moisture, it is cooled, falls to the floor, and again

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passes through the heating coils. The resulting circulating is neither positive nor uniform and results in great unevenness in temperature and drying rate. As evaporation would entirely cease if the air in the drier were continuously recirculated until it becomes saturated with moisture, vents and fresh air openings are provided. These are arranged with regulating dampers which can be manipulated so as to give an approximate control of the relative humidity through the introduction of dry, fresh air. However, due to lack of positive circulation, rapid even drying cannot be obtained.

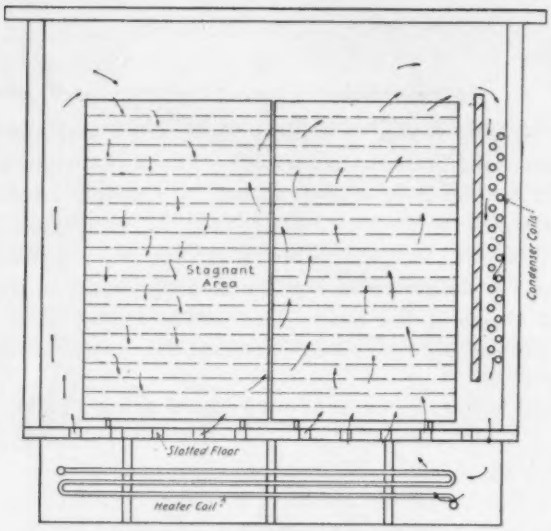


FIG. 2.—Drier using slotted floor and gravity circulation.

Figure 2 is a development from the first drier, using a slotted floor with the heating surfaces grouped underneath. The circulation of the air is by gravity. Later, condenser coils were added. Cold water was circulated through the coils in sufficient quantity to condense from the air, moisture evaporated from the material. The condenser coils also assisted in accelerating the movement of the air through the drier. Very uneven drying occurred in this type, due to no method of positive air circulation.

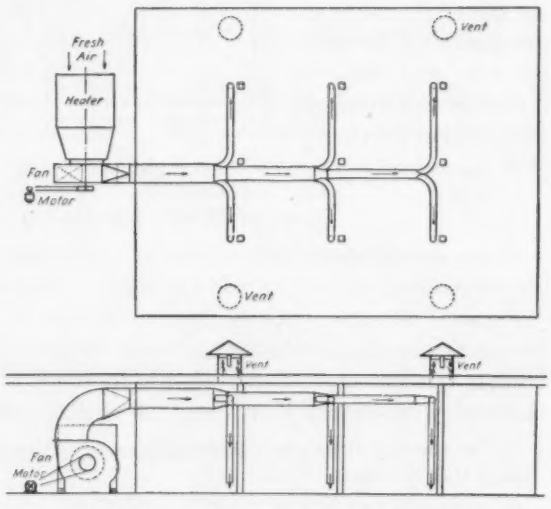


FIG. 3.—Early type of drier using forced circulation of air.

There are many variations of the

gravity type of drier and it is possible, with careful operation, to obtain successful results, but at a very *slow* rate.

The first driers with positive mechanical circulation were almost uniformly a failure. This was due largely to the method used in air introduction and utter lack of any provision for humidity control.

Figure 3 shows one of the earlier arrangements of apparatus and air distribution. It will be noted that only fresh, dry air passed through the apparatus, which was discharged through drop pipes against the floor and then passed up through the material and escaped through the vents in the ceiling.

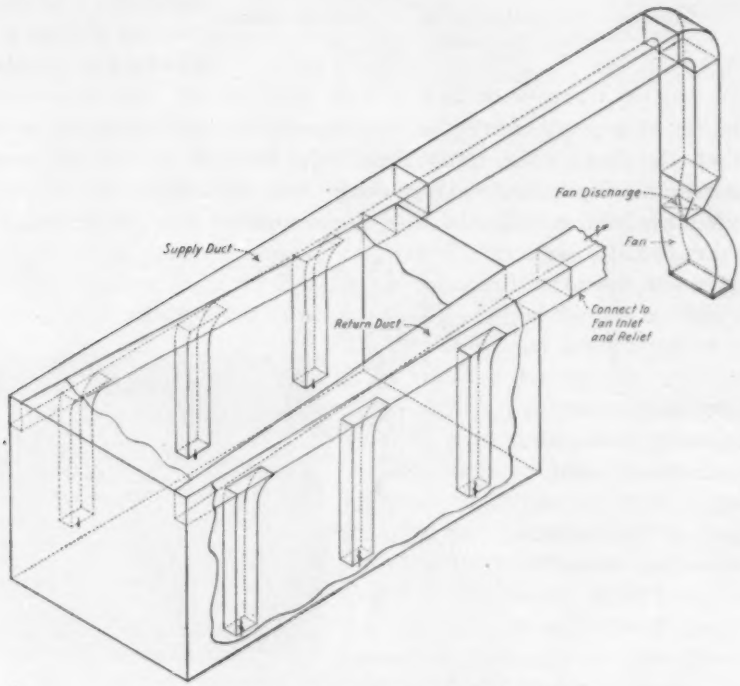


FIG. 4.—Drier using forced recirculation of air.

As a result of this exposure to extremely dry air, general injury to the ware often occurred. This type of drier was also very uneconomical as all the air used had to be heated from atmospheric temperature to the temperature of the drier, and then exhausted after one passage over the material. Unfortunately, it is impossible, with this method, as shown, to produce a rapid, even flow of air through the material. However, such a method of air circulation, if properly designed, might be made to give rapid, even distribution.

Another type of circulation with a fan, is shown in Fig. 4. In this case, the air is introduced through outlets near the floor, along one side of the room, and discharged by the same method from the opposite side. The air passed through the room unevenly, there being a zone of high velocity at the center, and very low velocity near the upper part of the room, along either side.

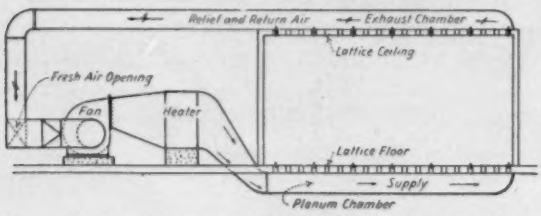


FIG. 5.—Mechanical circulation of air through perforated floor and ceiling.

Figure 5 illustrates a system of air circulation by mechanical means with lattice floors and ceiling. The success of this arrangement depends entirely on the proper ratio of air volume to openings through the floor. The resistance of the floor to flow of air must be greater than the pressure corresponding to the velocity of the air through the chamber underneath. In this way a uniform flow of air will result over the full area. With care in operation, this system should be able to give good results. This type of circulation is varied by using solid floors and perforated side walls.

Figure 6 is an example of mechanical circulation using the disc type of fan in place of the centrifugal housed fan. In this figure, the air is drawn through the material, although this may be varied by reversing the direction of the air flow. In this case there is a direct blast of air on the material with the necessary unevenness of drying rate. The mechanical efficiency of

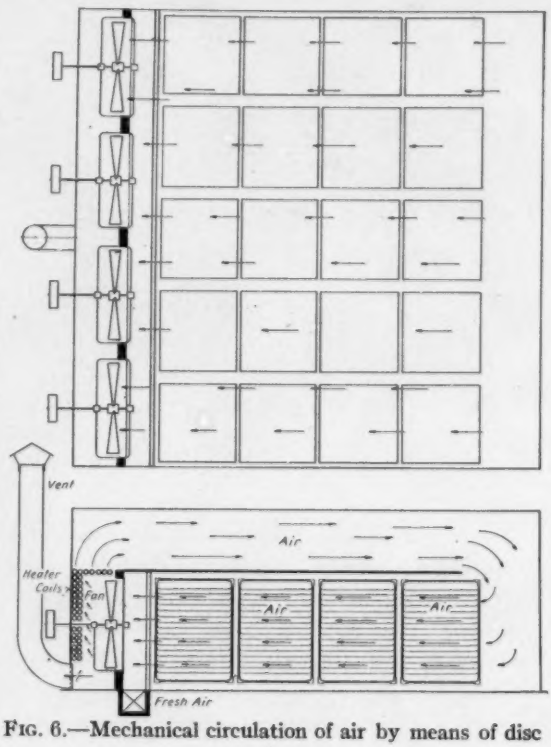


FIG. 6.—Mechanical circulation of air by means of disc fans.

the propeller type of fan is much lower than that of other types of fans, which makes the installation inefficient from the power standpoint, except for the fact that low pressures are usually required.

One of the most recent improvements in the method of air circulation and distribution is the ejector system, which is illustrated in Fig. 7. This system employs the highly efficient, housed, centrifugal discharge fan, discharging the air through nozzles at high velocity. Due to the high velocity of this air, a secondary current, three to five times the original volume, is set in circulation. The ejector nozzles are placed along one side of the room, near the ceiling, discharging the air over the material. This air mixes thoroughly with the larger volume of room air as it passes across the top of the material. As it reaches the far side of the room, it is deflected downward along the wall from where it passes backward, horizontally through the material, in an opposite direction from the discharge of the nozzles. Due to the resistance to the flow of air offered by the material, a slight pressure is built up on the farther side of the room, thus equalizing the flow through the material and maintaining a strong uniformly distributed current over the drying surfaces.

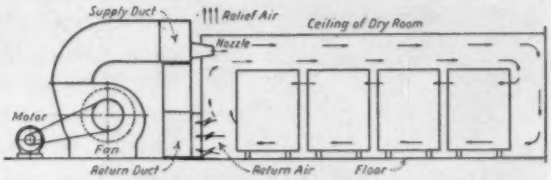


FIG. 7.—The ejector system of air circulation.

FIG. 8.—Ejector room, drying terra cotta on pallets.

The ejector system is a development of great importance because it makes possible the circulation, within the drier, of much larger volumes of air than are possible otherwise. This is so, because an apparatus which will condition and propel a given volume of air can, by means of this system, circulate within the drier, three to five times as much air as introduced.

Several methods of arrangement of material are used with this system. The material may be placed on pallets, as illustrated in Fig. 8. The pallets are moved in and out of the drier on lift trucks.

Figure 9 shows one method of handling sanitary ware on stillage. These racks are moved on lift trucks, which allows loading at the point of reworking.

Figure 10 illustrates a method of handling by means of an overhead trolley system. In this case, the stillage is reloaded at the rework bench.

It is then moved into the drier and after drying, to the sanding and inspection departments.

Temperature and Humidity Control

The foregoing has been a description largely of methods of air circulation, which is one of the prime necessities of successful drying. However, it is as important to be able to control the drying conditions, as well as to have proper air circulation. Since the rate of drying depends not only on the air velocity, but also on the difference between the wet bulb temperature and the dry bulb temperature, the rate of evaporation must not be greater than the rate of moisture diffusion through the material. This may be stated in another way, as follows:

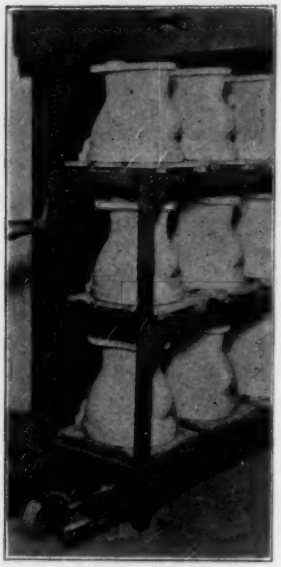


FIG. 9.—Ejector room, drying sanitary ware on racks.

That the evaporation from the surface of the body must not be in excess of the movement of the moisture from the interior to the surface. As the rate of diffusion is a function of the temperature, it is necessary for rapid, successful drying, to increase the temperature of the material to as high a temperature as the piece will stand without injury. The temperature of the material, so long as it remains above the "particle saturation point," will be approximately at the wet bulb temperature of the air; so, by controlling the wet bulb temperature, it is a simple matter to control the temperature of the material, or rate of diffusion. Under conditions of constant air movement, it is necessary to control the wet and dry bulb temperatures of the air, in order to control the rate of successful drying.

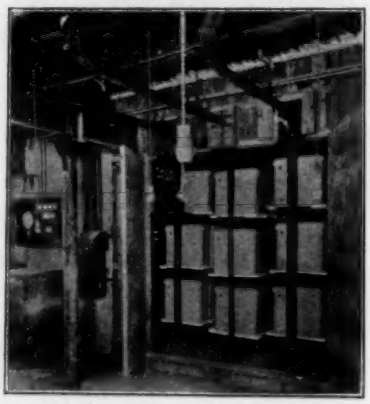


FIG. 10.—Ejector room, drying sanitary ware on racks moved by overhead trolley system.

Instruments for Automatic Control

Highly developed instruments for the control of conditions, as cited above, are now in general use. Such instruments are affected, either by the wet bulb and the dry bulb temperatures directly, or by the dry bulb temperature and the relative humidity. The first condition

requires two thermostats, one exposed to the dry bulb temperature and the other wetted and affected by the wet bulb temperature. The second condition requires a dry bulb thermostat and a hygrostat with a hygroscopic member, affected by the relative humidity of the air. This is permissible, inasmuch as the difference between the wet bulb and dry bulb temperature remains approximately constant, for any given relative humidity. This difference increases slightly with an increase of temperature, so that a slight drying effect may take place during the last part of the heating-up period. The following examples are given as typical of methods of automatic wet bulb and dry bulb controls:

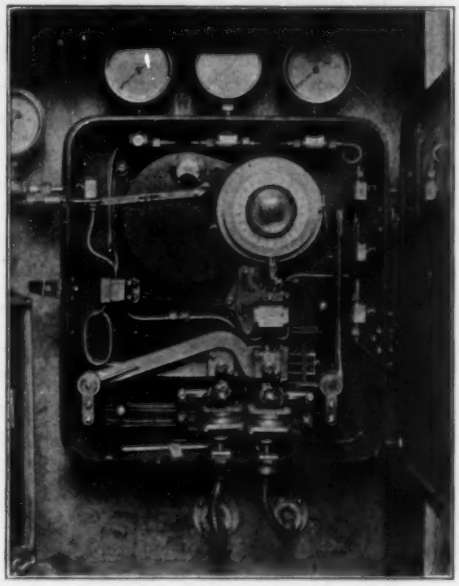


FIG. 11.—The Thermotyme automatic control for wet and dry bulb temperatures.

Figure 11 illustrates the Thermotyme wet and dry bulb control. This instrument embodies, in one case, two variable thermostats, one controlling the dry bulb temperature by means of admission of steam to the heaters, and the other, the wet bulb temperature, through a steam spray or other humidifying device. The control setting of these thermostats is continuously changed, according to a predetermined schedule. This is accomplished by means of cams "*A*" and "*B*," which are driven by a clock. The action of the cams changes the setting of the thermostats automatically in a more accurate manner than can be done by hand, and are independent of the human element. As the temperature and wet bulb depression will be the same during every run, the rate of drying will be the same every day, irrespective of loadings of outside atmospheric conditions. However, the instrument is not restricted to one drying schedule by the shape of the cams. Should it be desirable to raise or lower the temperature plane of the entire schedule, this can be done by a simple adjustment under

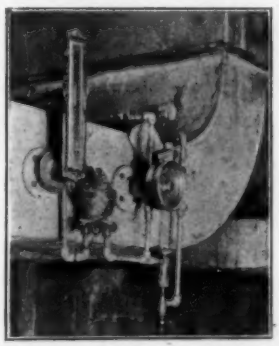


FIG. 12.—Control for temperature and relative humidity.

the valve block. If it is possible to reduce the duration of the heating-up period, this can be accomplished by an adjustment at the side of the instrument. By changing the speed of the clocktrain, the entire schedule may be shortened or lengthened. So, the drying of many pieces of different characteristics can be carried on under schedules best suited for their requirements.

Another type of ceramic drier control is illustrated by Fig. 12. This is of particular value in the drying of materials which are not sensitive to slight changes in the length of schedule. The action of this control is to maintain constant relative humidity by a hygrostat and humidifying device throughout the heating-up period, at the end of which the hygrostat is automatically cut out of the system by a thermostat, and the drying proceeds under dry bulb control alone. In this case, the humidity is gradually decreased by infiltration of the outside air, until the end of the drying period.

Drying Schedules

As the maximum rate of drying, without injury, depends on the characteristics of the mix and the shape of the piece, it is necessary to determine the proper drying schedule to fit each individual case. However, experience has shown that in general, different types of material will have the same characteristic schedules. These may be modified somewhat, due to different clays, etc.

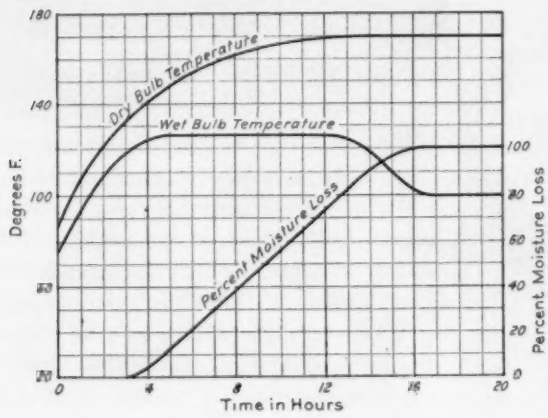


FIG. 13.—Typical terra cotta drying schedule.

Figure 13 illustrates a general schedule of drying for terra cotta, for pieces under one hundred pounds. This schedule has the characteristic heating-up period, which extends over the first three hours. In this case, the temperature increase is more rapid than would be possible with mixes of more delicate ware. The conditions during the drying period show a rapid increase in dry bulb temperature, with a decreasing wet bulb, which is most favorable for a rapid rate of evaporation.

As the final amount of moisture left in the material is dependent upon the difference between the wet bulb and dry bulb temperatures, it is necessary to reduce the wet bulb to a low point at the end of the drying period.

The amount of moisture which may safely be left in a piece, at the end of the drying period, depends on the rate of firing in the kiln. If slow, 4% to 6% will not cause any damage, but if rapid, 2% would seem the point to be the maximum.

In general, the rate of change in temperature of the piece itself, and the rate of evaporation from the surfaces, are the determining factors in the arrangement of a drying schedule. As the variation of temperatures in the piece depend on air circulation, as well as upon temperature and the relative humidity, it will be seen that schedules will vary for different types of driers, for drying the same material.

Conclusion

The benefits to be derived by modern drying equipment employing reliable control of temperature and humidity and air movement, have been well demonstrated by several successful installations in large plants of this country. Although there is much that can yet be accomplished in drying practice, and this must be done by the proper coöperation of the progressive manufacturers and those who are specialists in the air conditioning field, the early experimental stages have been passed.

Installations of the nature described are successfully drying sanitary ware, whiteware, tile, terra cotta, refractories, glass pots, electrical porcelains and other of the finer grades of ceramic products.

The improvement in drying practice accomplished by modern systems may be stated in terms of definite profit to the manufacturer; drying breakage is reduced to a minimum; the time of drying is standardized; the amount of unfinished ware in stock is cut to a minimum and the floor space for drying is reduced to a small percentage of that formerly necessary.

CARRIER ENGINEERING CO.
NEWARK, N. J.

THE OXIDATION OF CERAMIC WARES DURING FIRING.[1] VI. A LABORATORY STUDY OF THE EFFECT OF VARYING THE RATE OF GAS FLOW AND OF HEATING ON THE DECOMPOSITION OF PYRITE IN CLAY

By Frederick G. Jackson[2]

ABSTRACT

This investigation shows that varying the rate of heating has little effect on the evolution of sulphur as gases from pyrite. Varying the rate of atmospheric flow, however, exerts a very marked effect. With a rapidly moving atmosphere the sulphur is 90% removed below 510°C (950°F), even when heated rapidly. Explanations are made and the application of the results to industry is pointed out.

Hitherto in the laboratory study of the evolution of sulphur from clays,[3] the rate of gas flow and the heating schedule have been held constant and the effects of different atmospheres and of different impurities in the clay studied. In the present investigation, a constant atmosphere (100% excess air) and a constant impurity, pyrite, a very common one in commercial clays, are used. The rate of gas flow and the rate of heating are varied.

The effect of varying these conditions is studied because from theoretical considerations, it was thought that they must have a very great bearing on the chemical reactions which take place in the firing of pyrite bearing clays.

Method of Procedure

The general methods used in preceding investigations were followed exactly. A number of bars were made up, using for each one 60 grams of the same secondary kaolin that was used before and $1^1/_2$ grams of pyrite, ground to pass 60-mesh. These bars were dried at 110°C. For each test a bar was heated in the electric resistance furnace, an atmosphere of known composition was passed through the combustion tube at a carefully regulated speed, and the sulphur in the exit gases was absorbed and analyzed. This apparatus has already been fully described and a photograph shown.[4] In the present investigation an entering atmosphere of uniform composition was used in all tests. It was approximately equivalent to 100% excess air in a coal fired kiln, and was made up as follows: 10% CO_2, 40% N_2, 50% air. This atmosphere was prepared in 20-liter bottles. It was applied at three different rates in the different tests, namely, 5, 10 and 20 liters per hour. In previous similar studies[5] the gas was passed

[1] Published by permission of the Director, U. S. Bureau of Mines, Department of the Interior.

[2] Associate Chemist, Ceramic Experiment Station, Bureau of Mines.

[3] *Jour. Amer. Ceram. Soc.*, **7** [4], 223; [5], 382 (1924).

[4] *Loc. cit.*

[5] *Loc. cit.*

at a rate of approximately 10 liters per hour. The importance of carefully controlling this rate was not at first fully recognized. In consequence, some of the results obtained were somewhat difficult to explain.

These particular rates of gas flow were selected after a study of results obtained in tests on commercial kilns.[1] In the third industrial study described, the rate of gas flow through the kiln during the first part of the sulphur evolution averaged 14 liters of cool gas for every 60 grams of charge. The amount of surface exposed per unit weight was five times as great in this work as in a commercial kiln.

The heating schedule used in previous studies was also maintained in this work. It had been derived from the first industrial study by dividing the hour factor of the schedule by ten, after attaining 425°C in the first hour. In the present investigation the temperatures attained in equal intervals of time were always the same as in the previous work. The length of these intervals was varied in the different series of tests. Thus in one series, two hours were allowed to attain each temperature of the schedule, in another series one hour, and in a third series one-half hour. The schedules were as follows:

TABLE I

HEATING SCHEDULE

Slow heating (hours)	Medium heating (hours)	Rapid heating (hours)	Temp., deg. C
2	1	½	425
4	2	1	445
6	3	1½	480
8	4	2	510
10	5	2½	560
12	6	3	615
14	7	3½	665
16	8	4	775

The absorbers for SO_3 and SO_2 were changed at the end of each interval and the amounts of gases absorbed were determined. A test was made with each rate of atmosphere passing at each rate of heating. This made nine tests.

Results

The results of these nine tests are recalculated as the percentage of the total amount of sulphur that was given off during each interval. This was done uniformly with results in previous work.

These results may give a clearer impression if presented graphically. The method used in the previous work is used here and cumulative results are plotted. In each figure, any point on the lower curve represents the

[1] *Jour. Amer. Ceram. Soc.*, **7** [8], 634 (1924).

TABLE II

PER CENT OF SULPHUR EVOLVED. FIVE LITERS OF GAS PASSING PER HOUR

Temp., deg. C	Slow heat (16 hours) as SO_3	Slow heat (16 hours) as SO_2	Medium heat (8 hours) as SO_3	Medium heat (8 hours) as SO_2	Rapid heat (4 hours) as SO_3	Rapid heat (4 hours) as SO_2
425	0.15	3.25	0.20	3.12	0.19	3.77
445	1.62	24.32	2.30	40.40	1.35	26.79
480	0.26	13.18	0.18	6.78	0.17	2.49
510	.29	0	0	.08	.09	0.25
560	.48	10.75	0	.07	.18	.28
615	.14	.38	0	.10	.20	1.69
665	.15	.37	0	.10	.08	0
775	.38	40	0	.05	.02	.55
Totals	3.47	52.65	2.68	50.70	2.28	35.82
Total per cent sulphur evolved in test	56.12		53.38		38.10	

TABLE III

TEN LITERS OF GAS PASSING PER HOUR

Temp., deg. C	Slow heat (16 hours) as SO_3	Slow heat (16 hours) as SO_2	Medium heat (8 hours) as SO_3	Medium heat (8 hours) as SO_2	Rapid heat (4 hours) as SO_3	Rapid heat (4 hours) as SO_2
425	0.94	33.90	0.25	1.04	0.11	2.16
445	2.82	41.35	2.02	36.34	1.56	27.36
480	2.32	4.95	3.20	40.37	1.42	30.68
510	0.22	.05	0.36	0.25	0.11	1.22
560	.42	.20	.10	.05	.98	14.13
615	1.13	.40	.21	.15	.19	1.45
665	.39	.30	.08	.20	.06	0.15
775	.78	0	.22	.15	.16	0
Totals	9.02	81.15	6.44	78.55	4.59	77.15
Total per cent of sulphur evolved in test	90.17		84.99		81.74	

TABLE IV

TWENTY LITERS OF GAS PASSING PER HOUR

Temp., deg. C	Slow heat (16 hours) as SO_3	Slow heat (16 hours) as SO_2	Medium heat (8 hours) as SO_3	Medium heat (8 hours) as SO_2	Rapid heat (4 hours) as SO_3	Rapid heat (4 hours) as SO_2
425	1.98	35.48	0.80	31.15	0.41	11.95
445	8.61	46.87	2.28	51.75	1.06	45.20
480	1.11	0.10	2.72	1.60	0.71	19.30
510	0.89	0	0.65	0	1.47	9.25
560	.45	.10	.27	.10	0.60	0.45
615	.67	0	.36	.15	.39	.30
665	.48	.05	.24	.10	.41	.20
775	0	0	.80	.30	.70	.60
Totals	14.19	82.60	8.12	85.15	5.75	87.25
Total per cent of sulphur evolved in test	96.79		93.27		93.00	

precentage of total sulphur evolved up to that temperature as SO_3 and the upper curve the percentage of total sulphur evolved in all forms. The difference between the two curves represents sulphur as SO_2.

Figure 1 shows the three tests when the gas was passed slowly, five liters per hour. Figure 2, when the gas was at a medium speed—ten liters per hour, and Fig. 3 when the rapid rate of twenty liters per hour was used.

The yields of sulphur in each case are summarized in the following table:

TABLE V

TOTAL PERCENTAGE OF SULPHUR YIELDED UNDER VARYING CONDITIONS

	Slow heat	Medium heat	Rapid heat
Slow gas	56.12	53.38	38.10
Medium gas	90.17	84.99	81.74
Fast gas	96.79	93.27	93.00

Discussion of Results

These results bring out very strikingly the object of the investigation. *Changing the rate of gas flow has a much greater effect on the yield of sulphur at low temperatures than changing the rate of heating.* A mathematical formula might be derived for this. It would, however, probably be of little value because in actual practice, there are too many variables involved.

Calculation shows that twenty liters of the gas mixture used contains 1.20 grams of oxygen. This will burn an equal weight of sulphur to SO_2.

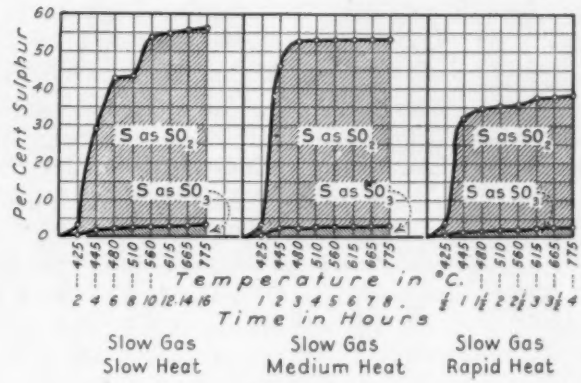


FIG. 1.

There were 1.5 grams of FeS_2 put into each clay bar. This amount contains 0.80 gram of sulphur. When FeS_2 first decomposes to Fe_7S_8 and S, three-sevenths of the sulphur is evolved. This weighs 0.343 gram. The oxygen to burn this is furnished by 5.7 liters of gas. To oxidize all the sulphur in a bar requires 14 liters of gas. The oxidation of the iron to Fe_2O_3 must

also be considered. This requires 0.30 gram of oxygen or five liters of gas. In all, nineteen liters of gas are required to furnish the necessary oxygen for the reaction.

To apply these figures, let us consider first the cases where gas was passing relatively more rapidly than the heat is being increased. In the extreme case (rapid gas—slow heat) 40 liters of gas were passed for every temperature interval. When the pyrite started to oxidize the temperature intervals were 20°C. Therefore enough oxygen was furnished, after the reaction began, to complete the oxidation before the temperature had increased by 10°C. The yield was 92.94% of the sulphur during the first two intervals. The remaining 7.06% of sulphur was evidently converted to $Fe_2(SO_4)_3$ almost completely since the gas evolved during the rest of the test was 3.60% SO_3 and 0.25% SO_2.[1]

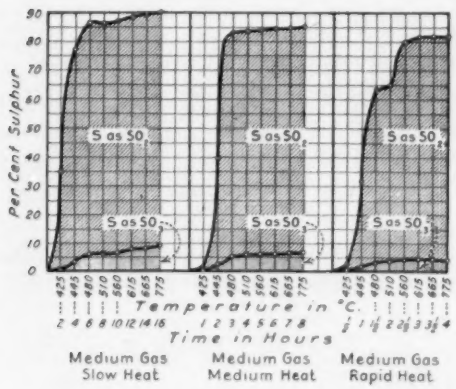


FIG. 2.

In the next group of tests, rapid gas—medium heat and medium gas—slow heat, 20 liters of gas were passed for each temperature interval attained, and so there was enough oxygen furnished to complete the oxidation before the temperature had increased by 20°. Yields were high, 93.27% and 90.17%, the more rapidly moving atmosphere giving the better yield. In both these cases, after the third interval, the bulk of the gas evolved was as SO_3, indicating that the remaining sulphur had been oxidized, probably to $Fe_2(SO_4)_3$ which in turn was decomposing at the higher temperature.

In the three cases where rate of gas flow and of heating were relatively the same, sufficient oxygen to complete the oxidation of the pyrite was furnished every two temperature intervals, or while the pyrite was being heated 45°. Yields were 93.00%, 84.99% and 56.12% depending on the rate of gas flow. When the gas was moving rapidly and sweeping away the products of combustion as rapidly as they were formed, the yield was high. But if the SO_2 formed could lie in contact with oxidizing iron, it was absorbed by it. In the fourth paper of this series it was shown[2] that the tendency to form ferric sulphate from Fe_2O_3 and $SO_2 + SO_3$

[1] In the second paper of this series (*Jour. Amer. Ceram. Soc.*, **7** [5], 384 (1924)) it was found that in 100% excess air ferric sulphate was practically stable until heated to 560°C and then decomposed evolving more SO_3 than SO_2.

[2] *Jour. Amer. Ceram. Soc.*, **7** [7], 532 (1924).

doubled between 350° and 415°. It was shown that some complex, stable up to higher temperatures, and referred to as "ferrous sulpho-silicate" was readily formed at these temperatures. In the test with slow gas and slow heat, it is evident that both of these compounds are formed to a considerable extent. There is an evolution of 11.23% of sulphur during the fifth interval, indicating ferric sulphate, but 43.88% of the sulphur was not evolved by the end of the test, which would point to the formation of a more stable complex.

With medium gas—rapid heat we find the same kink at the same place in the curve, indicating the presence of ferric sulphate. In this test, as with slow gas—medium heat, sufficient oxygen for the oxidation was furnished every four temperature intervals. Even the 5.7 liters of gas needed to oxidize the first part of the sulphur, by the reactions:

$$7\ FeS_2 = Fe_7S_8 + 6\ S$$
$$6\ S + 6O_2 = 6\ SO_2$$

was not supplied for more than an hour. In consequence, when the first reaction took place rapidly of its own accord, the second continued until the oxygen supply was exhausted. The remaining sulphur then was free in elemental form. It was washed over, in an atmosphere of N_2 and SO_2, by the water of constitution of kaolin which is given off at about this temperature. This elemental sulphur could readily be seen in the absorbers.

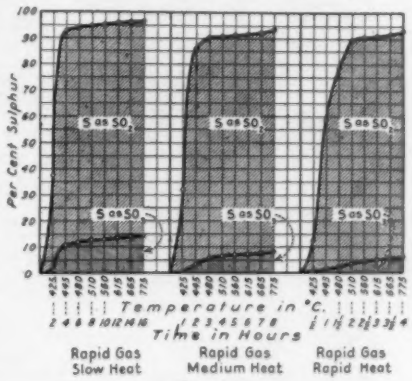


FIG. 3.

It is evident that almost all of the remaining sulphur is combined as the more stable complex, since, after the third interval there is practically no sulphur evolved.

With slow gas—rapid heat, during the entire test there was only just enough oxygen passed to perform all the oxidation required. The main yield of the sulphur came in elemental form during the second interval. After that the Fe_7S_8 remaining could oxidize only slowly in insufficient oxygen and at high temperature. The tendency would therefore be to form the more stable complex.

Conclusions

Pyrite may be readily and almost completely decomposed at low temperature if sufficient oxygen is provided. The oxygen need not be concentrated, as was the case in some previous laboratory tests, but need be

only 10% of the atmosphere. This atmosphere, however, must be moving rapidly, to give good yields. Thus enough oxygen is provided and the sulphur gases are swept away before the temperature increases greatly. In experiments where volume of gas per temperature interval is the same, the more rapidly moving gas gives the greater evolution of sulphur. If the sulphur gases are not removed rapidly, they recombine with active materials in the ware to form compounds which are decomposed only at higher temperatures. If such compounds are formed in large amounts, their decomposition may injure the ware.

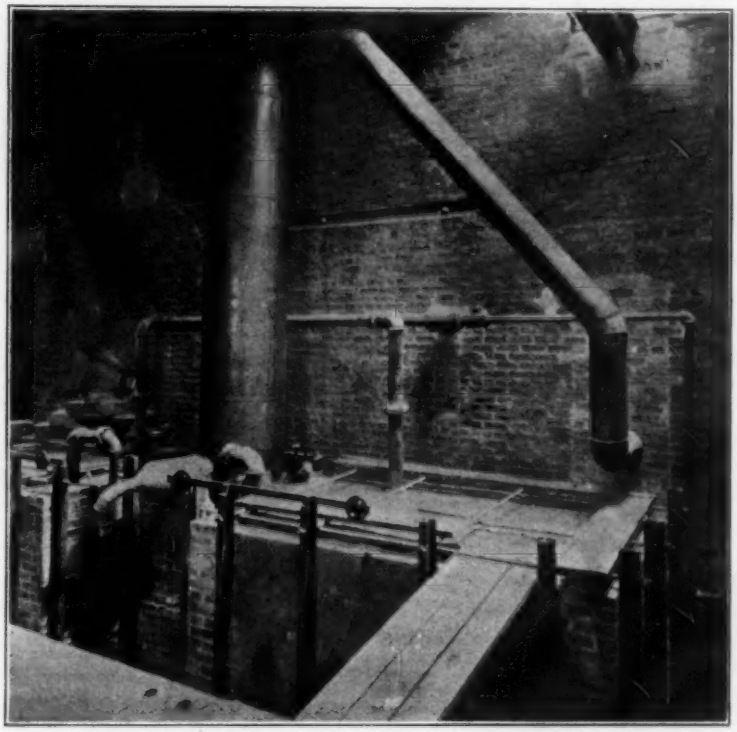
RECUPERATOR OIL SMELTER[1]

By Robert MacDougall

ABSTRACT

A recuperator was built at small cost to serve a unit of two oil-fired smelters. These smelters have shown a fuel saving of $2500.00 per year over cost of coal for smelters formerly used, besides saving the labor of one man. An improved product results from better furnace control possible with oil fuel and preheated air for combustion.

A year ago our producer coal smelters were in need of replacement. After considerable study we decided to design and build four oil smelting furnaces. These furnaces were designed and built, two furnaces to a unit,



a common stack serving both. Two of these furnaces were built so that their operation could be studied before building the additional furnaces.

The efficiency of the average smelter is very low, perhaps as low as any commercial furnace of any type. In designing these oil furnaces we set

[1] Presented at the Annual Meeting, American Ceramic Society, Columbus, Ohio, Feb., 1925. (Enamel Division.)

out with the idea of increasing the efficiency, and at the same time get maximum heat control.

These furnaces are the common type smelter, each having a single pot or tank made up of 20–24 inches by 12 inches by 6 inches Laclede-Christy No. 30 mix flux blocks. A common stack is located in the five-foot space between and near the back of these furnaces. The burner and flue openings are on the same end of each furnace, about 3 feet apart. A 6-inch square opening is provided in the center of the arch for charging the mix and a 10-inch square sliding door is placed in the front above the spout and pot for stirring the smelt. The total combustion volume above the pot is 50 cubic feet. The flue area is 90 square inches, and the stack diameter is 18 inches. The stack is divided to 18 inches above the flues.

The efficiency of an ordinary smelter is low, due principally to: (1) high temperature of flue gases, (2) radiation loss, (3) oxidizing atmosphere maintained.

The greatest opportunity to save fuel is utilization of a portion of the heat in the flue gases, as this loss is usually 70% or more in a furnace of this type. The radiation loss may run around 15%. Twenty per cent excess air in the furnace will account for a loss of perhaps 8%. If 30% of the radiation loss could be saved through insulation, only a 5% increase in efficiency would result. However, if 30% could be saved from flue gases an overall saving of 23% would be effected. There has always been a question of the practicability of insulation on high temperature furnaces.

On glass tanks, regeneration is common practice, but this is impractical for furnaces intermittently operated. The practicability of a metallic

recuperator, using 2600°F flue gas with the other corrosive gases from the smelt is perhaps questionable. We solved the recuperator problem in a very simple manner.

The stack is 10-gage steel, 27-inch diameter by 24 inches high, lined with Mount Savage arch brick, leaving a flue 18 inches in diameter. The stack was made in two lengths bolted together; the lower part 14 feet long being arranged for a recuperator by the addition of an air-tight outer steel casing 30 inches in diameter with a 12-inch air inlet introduced at the top off center. The outlet is at the bottom and off center, as at the top, causing the air to swirl around the stack in a narrow stream.

The burners used are special No. 4 Hagan Burners with a capacity of 12 gallons of oil per hour. One burner is used on each furnace. The

burner has a $2^1/_2$-inch atomizing air connection and a 4-inch combustion air connection. The atomizing air at $1^1/_2$ pounds pressure is preheated to 200°F in a pipe coil in the brickwork of the arch. The combustion air is introduced at a pressure of about $^1/_2$ ounce and is preheated in the stack to 500°F. An asbestos shutter is provided to slide in front of burner nozzle when burners are shut off. It is not necessary, however, to use this shutter when the burner is shut off for the short time during charging.

A comparison of the fuel cost of operating the old and new furnaces is interesting.

Each of the coal producer furnaces had two pots; the front pot was used to smelt white, and the back pot first coat enamel. The output of each furnace per 24 hours was as follows:

11 charges of 470 lbs. white or	5170 lbs.
8 charges of 304 lbs. first coat	2432 lbs.
Total	7602 lbs. or 3.80 tons enamel mix

Fuel used: Franklin County R. O. M. at $2.75	$2.75
Freight	1.95
Unloading	.35
Wheeling coal to smelter, clinkering, handling ashes	.75
Total cost per ton to burn	$5.80
2.5 tons coal per 24 hours	2.5
Fuel cost per day	14.50
Cost per ton enamel mix smelted	3.81

One oil smelter will smelt 13 charges of 940 lbs. white or 12,220 lbs. per 24 hours. Fuel consumption 240 gallons.

Fuel 240 gallons oil at 5 cents	$12.00
45 kw. hr. for air, etc., at 2 cents	.90
Fuel cost per day for 6.1 tons enamel mix	$12.90
Cost per ton enamel mix smelted	$2.11

The above figures show the costs on the basis of the weights of enamel mix smelted. The figures given below are on a basis of 18% loss in batch weight or frit weight.

Comparative B.t.u. required and cost of frit.
Coal smelter (14,000 B.t.u. coal). Oil smelter (142,000 B.t.u. oil)

	Cost		Cost
1 Ton frit requires 1608 lbs. coal	$4.66	1 Ton frit requires 48 gal. oil	$2.58
1 Ton frit requires 22,512,000 B.t.u.		1 Ton frit requires 6,816,000 B.t.u.	
1 Lb. frit requires 0.8 lbs. coal		1 Lb. frit requires 0.024 gals. oil	
1 Lb. frit requires 11,200 B.t.u.		1 Lb. frit requires 3,408 B.t.u.	

These figures show a fuel saving of ($4.66−$2.58) = $2.08 per ton of frit. In smelting 100 tons of frit per month, which is a fair average, an annual fuel saving of $2,500 would be realized. It is interesting to note that with coal at $5.80 per ton and oil at 5.373 cents per gallon, 100,000 B.t.u. costs 2.00 cents for coal, and 3.8 cents for oil. In other words oil costs 90% more on a strict heat unit basis. The fuel savings shown is possible due to increased furnace efficiency.

Labor Saving We have been able to save the labor of one man in the Smelting Department.

Saving Floor Space As the unit built has sufficient smelting capacity for some time to come the second unit of 2 smelters we proposed to build will not be built. The space used for coal storage is now used for productive purposes.

Conclusion

The oil smelters built are less complicated than the coal producer furnaces replaced, and consequently will cost less to maintain. These furnaces have a greater capacity than the coal furnaces replaced. We find it requires just one-half the time to reline these furnaces compared to our coal smelters. White frit containing 417 batches or 375,000 pounds was smelted with one lining.

An effective means of recuperation was devised which saves fuel and allows better furnace control. This was accomplished at a cost no greater than the cost of building an ordinary brick stack. Keeping the brick in the stack cool should prolong the life of the brickwork. We find flue temperatures running one smelter is 1310°F at the top of stack.

The uses of oil fuel for smelting has eliminated coal dust and dirt in the smelting department and adjacent factory space used for mixing, milling, etc.

COONLEY MFG. CO.
CICERO, ILLINOIS

CORRECTION

Rebbeck, J. W., Mulligan, M. J., and Ferguson, J. B. "The Electrolysis of Soda-Lime Glass—Part II." *Jour. Amer. Ceram. Soc.*, **8** [6], 329 (1925). The ordinates of Fig. 3 should read 0.25 greater than they now do in all cases.

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CERAMIC ABSTRACTS

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Abrasives

PATENTS

Abrasive composition. HENRY R. POWER. U. S. 1,539,694, May 26, 1925. An abrasive composition comprising abrasive particles and a gum, said compn. being substantially free from either silicate of soda or oil, substantially as described.

Antislip material. OTIS HUTCHINS. U. S. 1,541,220, June 9, 1925. An antislip floor or tread surface having cement with fragments embedded therein, said fragments being broken portions of fused alumina masses having a porosity of at least 25%.

Art

A lecture on Sèvres porcelain. WILLIAM KING. *The Pottery Gazette and Glass Trade Review*, **50**, 574, 611–4(1925).—This is a report of a lecture delivered by K. at the Victoria and Albert Museum. The history of the Sèvres factory was outlined, with ref. to its influence on the history of European art. P. D. H.

Metallic luster. W. D. BANCROFT AND R. P. ALLEN. *J. Phys. Chem.* **29**, 564–86 (1925).—A physico-psychological study of luster. H. H. S.

Cement, Lime and Plaster

Portland cement industry in Canada. A. G. FLEMMING. *Canadian Chem. and Met.*, **9**, 117(1925).—Finally revised statistics on cement production as reported by the Mining, Metallurgical, and Chemical Branch of the Dominion Bureau of Statistics show sales of Canadian Port. Cement in 1925 totaled 7,498,624 bbls. valued at $13,398,411 as against 7,545,589 bbls. worth $15,064,661 in 1923. Exports were 153,520 bbls., a decrease of 340,231 bbls. Imports were 27,672 bbls. The consumption in 1924 was only 82% of the 1913 consumption. F. G. J.

Progress in ciment fondu in France. ANON. *Chem. Met. Eng.*, **32**, 494(1925).—Ciment fondu is fused in elec. fur. at 1400°C. Its high alumina content, 42%, is obtained from bauxite. It is ground in rotary grinders to a high degree of fineness. Its chief value is in its rapid hardening. Its resist. after 48 hrs. is superior to that of ordinary cement after 28 days. It is being used now for rapid relaying of pavements where there is an intense continuous traffic. Wheeled traffic can use such repaired roads after 24 hrs. M. E. M.

Some modern gypsum products. J. M. PORTER. *Chem. Met. Eng.*, **32**, 499–500 (1925).—Lists the gypsum structural products manufd. today. M. E. M.

Problems in cement and concrete research. C. R. PLATZMANN. *Rock Products*, **28** [9], 54–7(1924).—That the constitution of Portland cement has not found generally recognized determination is largely due to its being neither a pure chemical compound

nor of a pure physical or mineralogical nature. Thus research in this field has to deal with different combinations of methods. Investigations of Portland cement should cover the entire field of the system $CaO–Al_2O_3–SiO_2$. The effect of the substitution of Fe_2O_3 for Al_2O_3 offers new possibilities. The part taken by MgO must be considered from the four component system, $CaO–Al_2O_3–SiO_2–MgO$. Other problems are: (1) hydration and hardening from the colloidal standpoint, (2) special high strength cements, (3) wet *vs.* dry process of mfg., (4) kiln draft, (5) potash recovery, (6) revision of standards, for methods of testing, (7) effect of storage on cement, (8) the use of cement, (9) the causes of disintegration, (10) the effect of calcium chloride, (11) the aggregate, (12) the effect of acid and salt solutions. H. G. F.

Cements with high percentages of alumina. ANON. *Rock Products*, **28** [3], 48–9(1925).—In aluminous cements the weight of alumina is greater than that of silica, and the sum of the weights of alumina and silica are greater than the sum of the weights of lime and magnesia. Aluminous cements have been developed to withstand the action of sea-water containing $CaSO_4$. They can be made by clinkerization but due to their small softening stage it is the practice to fuse the clinker in water-jacketed or electric furnaces. Iron oxide is transformed into steel and a high temp. is required to run the steel. The composition of aluminous cements is based upon the four aluminates of calcium. They are preferable from the point of cost per resistance kg. They are also more elastic than Portland cement and the time of setting is much shorter.

H. G. F.

Magnesia Portland cement. K. BALTHASAR. *Rock Products*, **28** [10], 50–2 (1924).—To maintain the selling value of Portland cement with as much as 8% magnesia it is necessary to vary the standard process of mfg. The mechanical treatment of raw materials and clinker remains the same. In dealing with a raw mix free from $MgCO_3$ the proportion of $CaCO_3$ is brought to 76.6%. With a high $MgCO_3$ content the percentage of $CaCO_3$ must be altered to maintain a ratio, $\frac{CaO}{SiO_2 + R_2O_3} = 2.10$, in order to produce a setting clinker. The calcination of high magnesia cement varies somewhat. The cement if properly made is equivalent to ordinary Portland cement. H. G. F.

Effect of end condition of cylinder on compressive strength of concrete. HARRISON F. GONNERMAN. Structural Materials Research Lab., *Bull.*, **14**, May 28, 1925. (*Proc. A. S. T. M.*, 1924.)—Experience has shown that it is not always practicable to obtain perfect workmanship in the making of test cylinders. A common defect in test cylinders made in the field is uneven end surfaces. These tests were made for the purpose of detg. the effect of uneven and irregular ends and to study the effect of different methods of treating the ends in applying a compressive load. Other factors such as the use of spherical bearing blocks, the inclination of axis of specimen, and the deflection of the bed of the testing machine were also studied. About 3000 6 by 12-in. concrete cylinders of 1:7, 1:5, 1:3½ and 1:2 mix by volume were tested at ages of 7 days to 1 yr. The relative effect of the different end conditions was judged principally by the ratio of the strength obtained for a given condition to that obtained for a *standard method* specified in the "Tentative Methods of Making Compression Tests of Concrete" (Serial Designation C39–21T) A. S. T. M. This method requires that the cylinder be molded on a plane machined cast-iron base plate and that the top be capped when made by means of a machined cover plate and neat cement which has been mixed and allowed to stand 2 to 6 hrs. before use. Test to be made with a spherical bearing block on top of the cylinder. The principal conclusions from the tests were: (1) The standard method of molding and capping concrete cylinders with machined base and cover plates gave uniformly high strength, equal to or greater than that from any of the other methods. (2) For reliable results the use of an adjustable block with spherical bearing surfaces was found

to be essential. (3) Small errors (1/4 in. or less) in centering the bearing block on the cylinder had little or no effect on concrete strength. An error of 1/2 in. in setting, gave strength-ratios of about 90% for 1:5 and 1:3 1/2 concrete. Smooth troweled tops (cylinders molded on machined base plates) gave the following results: (1) With thin caps of gypsum or mixtures of cement and gypsum, the results were essentially the same as those obtained for the standard method of capping. (2) Without bedding, the strength-ratios obtained were about 95% for 1:7 concrete, 94% for 1:5 concrete and 80% for 1:3 1/2 concrete. (3) With sheet materials between top of cylinder and the spherical block, the strength-ratios obtained were less than 100% for all of the material used. (4) For the sheet materials, the best results were obtained with beaver board, which gave strength-ratios of about 100% for 1:7 and 1:5 concrete and about 90% for 1:3 1/2. (5) For white-pine board, mill board and leather, the strength-ratios ranged between those found for beaver board and those found for no bedding. (6) For the other sheet materials, blotting paper, sheet lead and rubber, the strength-ratios were less than those found for no bedding. (7) The lowest strength-ratios were found for the 1/16-in. sheet rubber—about 80% for 1:7, 70% for 1:5 and 50% for 1:3 1/2 concrete. Cylinders made and capped by the standard method, tested with a 1/2-in. segment (circular segment of 1/2-in. mid-ordinate) of the cap removed, gave strength-ratios slightly less than 100%. When a 1-in. segment was removed the strength-ratios obtained were 100% for 1:7 concrete, about 95% for 1:5 concrete and 90% for 1:3 1/2 concrete. The removal of a 2-in. segment gave strength-ratios of 90%, 80% and 65% for the three concretes. When the segments removed were replaced with 1:1 gypsum and cement mortar 3 hrs. before test, the strength-ratios were about 100% except for the 2-in. segment, which showed strength-ratios of from 95% to 90%. Cylinders with plane parallel ends but with axes inclined, gave the same strength as standard cylinders for an inclination of 1/4 in. in 12 in. and strength-ratios of about 92% for an inclination of 1/2 in. in 12 in. Cylinders with top surface inclined showed strength-ratios of about 100% for an inclination of 1/4 in. in 6 in. and of about 95% for an inclination of 1/2 in. in 6 in. Cylinders molded with machined cast-iron plates so as to give convex ends and tested without bedding, gave pronounced reductions in strength even for a small convexity. The strength-ratios were smaller the greater the convexity and the richer the mix. For a convexity of 0.01 in., the 1:3 1/2 and 1:2 mixes showed strength-ratios of about 65% and for a convexity of 0.05 in., about 40%. For the 1:7 and 1:5 mixes the corresponding strength-ratios were about 80% and 55%. When tested with beaver board sheets top and bottom, the reductions in strength were about half as great as without bedding. The use of gypsum bedding for one group of cylinders with bases convex 0.05 in. gave strength-ratios of about 90%. The effect of concave ends was small compared to that of convex ends. Sheared steel plates 8 in. square by 1/4-in. thick, from warehouse stock, showed deviations from a true plane of as much as 0.012 in. Cylinders molded with these plates as bases and covers so as to give convex ends, gave results comparable with those from cylinders having the same convexity, similarly made with machined cast-iron plates. Finally, the most important conclusion from these tests is that great care must be exercised when preparing concrete cylinders for test in order to secure plane ends. When the standard method of capping with plane cover plates cannot be followed, the cylinder should be troweled smooth and capped with a thin layer of gypsum, or a mixture of gypsum and cement, 3 to 6 hrs. before test. The cylinders may be conveniently capped by placing a small amount of the capping material on a plane metal or glass surface and pressing the end of the cylinder down upon it, taking care to keep the cylinder in a vertical position during the operation. The cylinders should always be molded on a plane surface; in testing field cylinders which have not been so molded, it is recommended that the ends be capped with a thin layer of neat cement 2 or 3 days before test, following the method described above for troweled tops. The Standards and Tentative Stand-

ards of the American Society for Testing Materials require that the cylinders be tested in a damp condition.

Storing cement. R. GRÜN. *Tonind. Ztg.*, **49,** 473–80(1925).—A comprehensive study of the effects of storage upon the quality of cement was made which included tests on 20,000 specimens. It was found that cement did not deteriorate very much up to 3 years if stored in air tight containers. Upon exposure to air the strength of the cement decreases about 8% in 6 months, 14% in 9 months, and 22% in 1 yr. There is very little difference between the resistance of different German cements to storage. H. G. S.

New building material made from Kieselguhr. ANON. *Quarry & Surveyors' & Contractors' Jour.*, **30,** 102(1925).—A new bldg. mat. made of kieselguhr, mixed with Port. cement and sawdust, is being extensively used in Austria and Czechoslovakia. Crushing tests have shown that diatomite blocks will stand 1100 lb. per sq. in., and that when stood on edge, as in walls, it will bear a load of 550 lb. per sq. in. The blocks can be used generally as a lining and ceiling mat., and as diatomite repels vermin, it would also help to overcome the objections on this score in connection with the new methods of bldg. in iron. The new mat. is fireproof. It is being manufactured in Vienna, Budapest and Prague. O. P. R. O.

Use of calcium chloride in concrete construction. ANON. *Chem. Record-Age*, **23,** 8–9(1925).—The better grades of commercial $CaCl_2$, today contain 73–75% $CaCl_2$. The product is considered to be $CaCl_2$, $2H_2O$. For use in concrete it is manufd. in flaked form and shipped in metal drums. It is best added as part of the gaging water, about 2–4 lbs., $CaCl_2$ being used per 100 lbs. of cement. It aids materially in placing concrete during cold weather, first by accelerating the time of set and allowing considerable strength to develop before the concrete freezes; and second, it produces a higher temp. within the concrete. $CaCl_2$ is also used on concrete highways for application on the surface instead of the usual layer of moist earth. By absorbing moisture from the air, it is dissolved and penetrates the concrete, leaving the surface moist. H. H. S.

The molecular volumes of water in hydrated calcium sulphates. W. BILTZ. *Zeit. anorg. allgem. Chem.*, **143,** 231–2(1925). H. H. S.

Influence of manganese on hydraulic properties of blast-furnace slags. R. GRÜN. *Stahl u. Eisen*, **44,** 1405–9(1924); *J. Soc. Chem. Ind.*, **44B,** 319(1925).—Cement made from manganiferous slag has a lower strength the greater the Mn content of the slag, especially for the first few days. If the Mn be practically eliminated by smelting the slag with C and Fe to produce ferromanganese and a Ca aluminosilicate, the slag has better hydraulic properties than the original slag before addition of Mn. The color produced in slag by addn. of MnO is first brownish yellow, then greenish yellow, and finally green. With 3% MnO, yellow fern-like inclusions may be noticed in the microstructure; with larger quantities the Mn constituent is pptd. in dispersed amorphous masses. H. H. S.

Effect of sulphide on blast furnace slags and cements. R. GRÜN. *Stahl u. Eisen*, **45,** 344–6(1925); *J. Soc. Chem. Ind.*, **44B,** 319(1925).—A fairly high sulphide content in slag, both natural and by addn. of CaS, is not injurious to cements; it increases the strength and does not accelerate setting. When present in small quantity, CaS forms an eutectic with the silicates, is taken up by them into solid soln. at higher temps., and on cooling separates out in dendritic form. When present in larger amt., it assumes globular form. H. H. S.

The mechanism of setting of calcium sulphate cements. C. L. HADDON. *Trans. Faraday Soc.*, **20,** 337–41(1924).—Theories of the mechanism of setting are examd., and the differences are shown between the hydration processes of plaster of Paris, flooring-plaster, and anhydrite. The varying effect of catalysts is thereby explained. As to cause of expansion, Desch's theory of crystal thrust is favored. Finally the

similarity of the coherence of $CaSO_4$ cements to that of metals (Rosenhain's theory of an amorphous cement between crystals) is pointed out. H. H. S.

Ternary systems CaO–Fe_2O_3–$CaSo_4$ and CaO–Al_2O_3–$CaSo_4$. W. H. MacIntire and W. M. Shaw. *Soil Sci.*, **19**, 125–52(1925); *J. Soc. Chem. Ind.*, **44B**, 293(1925).—Newly pptd. Fe and Al oxides adsorb CaO and $CaSO_4$ to form $3CaO.Al_2O_3.3CaSO_4.XH_2O$. The crystallography of this subs. and of calcium ferrate and aluminate is described, and its bearing on the disintegration of cement embedded in soil is discussed. H. H. S.

What is alite? Hans Kühl. *Zement*, **13**, 512(1924).—Because chem. analysis gives high Ca content, K. considers alite to be either an isomorphous mixt. of tricalcium silicate and tricalcium aluminate or a soln. of free CaO in dicalcium silicate and tricalcium aluminate. (*C. A.*)

What is alite? Oskar Schmidt. *Zement*, **13**, 543–4(1924).—Since chem. and microscopic analyses of alite crystals show considerable amts. of Al_2O_3 (2–8%), S. concludes that alite is a compd. of tricalcium silicate and a calcium aluminate. (*C. A.*)

BOOK

Aide-Memoire de Ceramique industrielle. Alix Cornille. Paris: Revue des Materiaux de Construction, 1924.

Enamels

Bonus system boosts production. Anon. *Ceramic Industry*, **4** [4], 278–80(1925).—The plant and opern. of the Challenge Refrigerator Co. of Grand Haven, Mich., is described. P. D. H.

Glass

Ford glass methods told in pictures. Anon. *Ceramic Industry*, **4** [4], 274–7 (1925).—This is a complete photographic presentation of the world's largest continuous-process plate glass factory. A tank requires 135 tons of flux blocks and 300,000 silica brick, which have a life of from 10 to 14 months. The following batch is fed to the tank every 15 min.

Sand	385 lbs.	Charcoal	2¼ lbs.
Limestone	125 lbs.	Arsenic	2¼ lbs.
Soda Ash	120 lbs.	Cullet	100 lbs.
Salt cake	33 lbs.		

The temp. in the tank, melting, is 2600°F, refining, 2225°F, and at the rolls 2050°F. The length of the leer is 442 ft. and the daily production is 40,000 sq. ft. P. D. H.

Conveyors save space in glass plant. Anon. *Ceramic Industry*, **4** [4], 292–4 (1925).—The plant of the D. O. Cunningham Glass Co., of Pittsburgh, Pa., is described. The product is flint and green bottles. Gas and oil are used as fuel. The oil is preheated to 200°F. The melting end of the tank is kept at a temp. of 2450°F and the refining chamber at 2200°F. The hot end of the 74 ft.-leer is held at 1025°F. The stack is located at the center. About 9 hrs. are required for the ware to pass through. P. D. H.

The use of zirconia in glass making. W. E. S. Turner. *The Pottery Gazette and Glass Trade Review*, **50** [574], 609–10(1925).—This is a report of a paper presented at a meeting of the Society of Glass Technology by T. In a series of glasses in which soda and silica, respectively, were replaced with from 10% to 20% zirconia, very little opacity resulted. In another series containing lime, from 7% to 8% of zirconia failed to produce opacity. When only a small quantity of zirconia was used, it was possible to melt the

glass at 1400°C. With larger amounts the melting was much more difficult and the resulting glasses did not possess the same long working range as glasses containing alumina, which latter type they resembled somewhat. The behavior of the zirconia glasses as regards annealing was similar to alumina-containing glasses. The use of zirconia did not produce glasses of lower thermal expansion, as had been hoped. When zirconia replaced soda, the chemical resist. to water was not as good as when titania replaced soda. When zirconia replaced silica to from 5% to 11% there was a marked improvement in the resist. to alk. solns. P. D. H.

Sillimanite in the glass industry. ANON. *The Pottery Gazette and Glass Trade Review*, **50** [574], 608–9(1925).—This article is a report of two papers presented at a meeting of the Society of Glass Technology. The first paper, which was presented by Mr. Cousen and Prof. Turner, was entitled "A Study of Sillimanite for the Purpose of the Preparation of Refractory Materials." The most plastic mixts. and those giving in fire clay the most stable and resistant pots were obtained by using sillimanite which had passed through a 100-mesh sieve. Good results were obtained when using 15% to 30% of ball clay as a bond. The porosity of hand-molded specimens was inversely proportional to the amount of bond used and with the addn. of 30% of ball clay reached as low as 22% at 1400°C. The mech. strength, both when 15% and 30% of bond was used, was greater than with fire clay refracs. Bentonite, when used as a bond, although giving the most plastic mixts., proved unsatisfactory in practice. The glasses were superior in color when melted in sillimanite refracs. The second paper, presented by F. G. Clark and W. J. Rees, was entitled "Some Notes on the Use of Sillimanite as a Glass Works Refractory." Tests made under commercial conditions showed that molten glass had very little effect on sillimanite refracs. They were also found to withstand the heat perfectly when used in the exit flues of furs. The best results were obtained with sillimanite bonded with from 10% to 25% of ball clay. The thermal condy. of sillimanite refracs. is higher than that of fire clay. Sillimanite was considered the best refrac. mat. known for use in the hottest part of any glass fur., either in contact, or out o fcontact, with glass. P. D. H.

The effect of composition on the viscosity of glass. Part III. S. ENGLISH. *The Pottery Gazette and Glass Trade Review*, **50** [574], 610–1(1925).—This is a report of a paper presented at a meeting of the Society of Glass Technology by E. The effect of magnesia and alumina, respectively, on the viscosity of soda-lime-silica glasses, was studied. The temp. range covered was from 1400°C down to the annealing points of the glass. The progressive substitution of equivalent molecular quantities of magnesia for lime decreased the viscosity until approx. equal mol. quantities of lime and magnesia were present. The effect of further substitution was to increase the viscosity. The rate of setting was distinctly decreased by the substitution of magnesia for lime and was progressive with continued substitutions of magnesia. The substitution of alumina for lime increased the viscosity at the melting temp., whereas in the lower ranges of temp. the viscosity was reduced. The rate of setting was distinctly decreased by the substitution of alumina for lime and, as with magnesia, was progressive with continued substitution. P. D. H.

The action of barium in glass. ANON. *Keramische Rundschau*, **33** [12], 192.—Translated in the *Glass Industry*, **6** [6], 125(1925). F. G. J.

Building and bottle glass as well as art glass at the Leipzig exposition. EDITORIAL. *Diamant*, **47** [10], 175(1925).—A description of the exhibition and a list of firms exhibiting. F. G. J.

Outline for the testing of product at glass works. Issued by the HANDWERKSKAMMER OF UPPER BAVARIA. *Diamant*, **47** [12], 225(1925).—A large number of general and special tests described. F. G. J.

The development of metal overlay decoration and cutting of glass. OTTO W. PARKERT. *Diamant*, **47** [13], 247(1925).—A short description of the various processes of glass decoration. F. G. J.

The danger from lead in the bottle and ornamental glass painting. F. GREINER. *Diamant*, **47** [13], 242(1925).—Retails the history of lead poisoning, a recognition of the symptoms and the method of cure. F. G. J.

How hot is the tank? S. R. SCHOLES. *The Glass Worker*, **44** [36], 13(1925).—Describes various possible errors in pyrometry with thermocouples. Advocates the use of optical pyrometers for checking. F. G. J.

How tank blocks of exact dimensions are made in the factory of the Ohio Valley Clay Co. ANON. *National Glass Budget*, **41** [5], 3(1925).—Description of mfg. process. Blocks are fired in a Dressler tunnel kiln and ground to exact dimensions by carborundum stones. F. G. J.

Raw materials of the glass industry. III. Salt cake and soda ash. I. J. B. KRAK. *The Glass Industry*, **6** [6], 123(1925).—Describes the methods of making salt cake. While it is cheaper than soda ash, it contains a lower per cent of soda, requires more fuel, is more corrosive, and gives poorer color. Salt cake must be reduced or it may float on the molten glass and form "salt" or "gall." F. G. J.

Bottle making in Indo-China. D. ROBERTSON. *The Glass Industry*, **6** [6], 115 (1925).—An account of glass mfg. conditions in the far East. F. G. J.

The photo-elastic constants of glass as affected by high temperatures and by lapse of time. F. C. HARRIS. *Sci. Abst.*, **28** [4], 264(1925); *Roy. Soc. Proc.*, **106,** 718–23 (1924).—Filon has previously experimented on the effect of temp. on the photo-elastic constants of glass by the flexure method, enclosing the specimen in a steam jacket giving a maximum temperature of 90°C. He observed a small increase in the stress-optical coefficient for the ray polarized perpendicularly to the line of stress. The present series of experiments now described were carried out with the object of extending the observations for temperatures up to near the melting point. The specimens consisted of small blocks of glass, 4 x 3 x 1 cm., and full experimental details are included. The specimen was observed through a Nicol's prism and a Babinet compensator in the light from a sodium flame polarized by reflection at a single glass plate. With the exception of one glass, which shows a decrease—an extra dense flint containing 64.4% of PbO—the stress-optical coefficient shows an increase with rise of temperature. This exception is in accordance with previous observations that the presence of large quantities of PbO tends to reverse all the known stress-optical properties. In every case examined the value of the stress-optical coefficient has increased with lapse of time. A. F. G.

The advisability of central gas generator for glass and similar plants. DICKE. *Sprechsaal*, **58,** 323–4(1925). H. G. S.

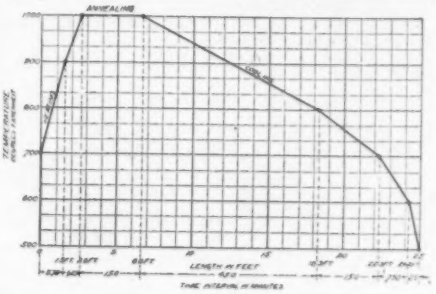
Elastic glass. ANON. *Discovery*, **6,** 151–2(1925).—A purely organic subs., "pollopas," made in Austria by F. POLLAK and K. RIPPER, resembles flint glass and is one of the most elastic subs. known. It is composed of carbamide and formaldehyde. It will take dyes selective of definite wave-lengths, and is also suitable for automobile panes, etc. H. H. S.

Resistance of laboratory glasses to chemical reagents. D. MIGLIACCI, R. TESTA AND A. SHUNDI. *Ann. Chim. Appl.*, **15,** 87–91(1925); *J. Soc. Chem. Ind.*, **44B,** 317 (1925).—Murano 1922 glass is slightly less resistant to reagents than Jena white mark, and considerably less resistant to change of temp. Thuringian glass is far more readily attacked, and Pyrex, although it offers great resistance to shock and change of temp., succumbs to alkaline solns. Preliminary exposure to steam at 140° renders glass more resistant to chem. attack, and such treatment is recommended for vessels where great accuracy is reqd. H. H. S.

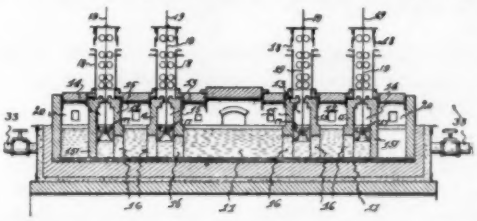
Effect of chemicals on various kinds of glass. C. E. KLAMER. *Chem. Weekblad.*, **22,** 140–1(1925); *J. Soc. Chem. Ind.*, **44B,** 317(1925).—Tables are given showing loss of wt. of Pyrex, Jena, Sphinx and Murano vessels after heating acids and alkalis in them. The conductivity of distd. water after boiling in selected vessels was detd. Murano and Pyrex are decidedly better than Jena in resisting the action of a mixt. of H_2SO_4 and P_2O_5. H. H. S.

PATENTS

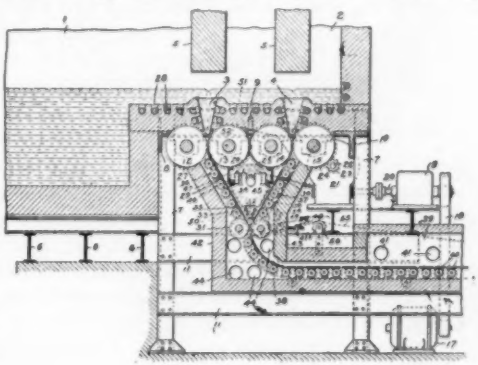
Process of annealing glass. KENNETH M. HENRY. U. S. 1,540,264, June 2, 1925. The method of annealing glass which consists in first htg. to a temp. less than the maximum annealing temp., maintaining this temp. for a length of time sufficient to partially remove internal stress and strain, cooling rapidly to the lowest annealing temp. of the glass being treated, and thereafter cooling more rapidly to atmospheric temp., whereby the internal stress and strain existing at the end of the htg. stage will be substantially neutralized during the cooling stage. The method of annealing glassware which consists in quickly htg. the glass to a temp. of approx. 1000°F, maintaining this temp. for approx. 15 min. and thereafter cooling the glass at the rate of 6° per min.



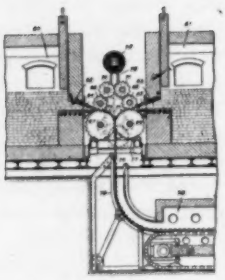
Glass furnace. JULES J. QUERTINMONT. U. S. 1,541,772, June 9, 1925. A glass fur. for drawing continuous sheets of glass, comprising a melting fur., a drawing tank communicating with said melting fur. and divided into a series of alternating drawing and reheating chambers in communication with each other and the melting fur., and terminating with a drawing chamber, a separate and independent htg. chamber adjacent to the end drawing chamber and not in communication with said drawing tank or melting fur. to revitalize the chilled molten glass passing into the end drawing chamber.



Method and apparatus for making wire glass. FREDERICK GELSTHARP. U. S. 1,541,637, June 9, 1925. In combination in app. for forming wire glass, a tank having a pair of parallel outlet slots, a pair of rollers at the exit end of each outlet adapted to receive there between the glass flowing from the outlet, supporting and guiding means in advance of each pair of rollers arranged to bring the two sheets together, means for supplying a metal mesh between the sheets and means for engaging the outer faces of the sheets and pressing them together.

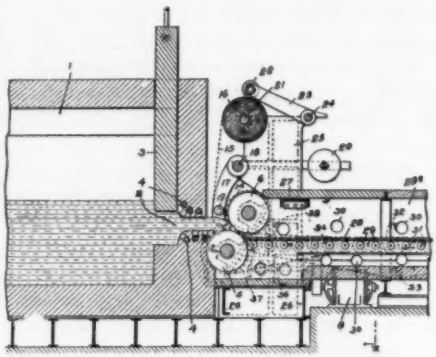


Apparatus for making corrugated wire glass. JOHN H. FOX.

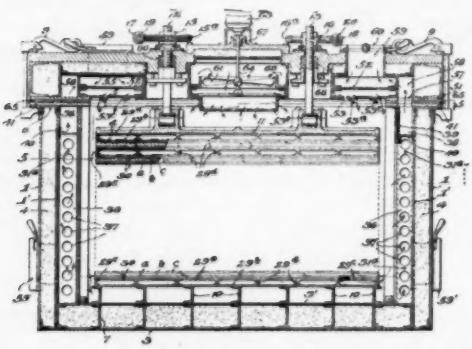


U. S. 1,541,635, June 9, 1925. A process of making wire glass which consists in continuously flowing two ribbons of glass so that they converge and meet, corrugating the sheets during such movement, continuously corrugating a wire mesh, feeding it between the two ribbons as they meet and applying press. to the outer faces of the ribbons to cause them to weld.

Method and apparatus for making wire glass. FREDERICK GELSTHARP. U. S. 1,541,638, June 9, 1925. App. for forming sheet glass comprising a tank containing a bath of molten glass and having an orifice leading through one of its side walls below the surface of the glass, a pair of cooled rolls opposite the orifice and spaced apart a distance corresponding to the thickness of the glass sheet to be produced, and with the upper roll spaced away from the tank, and a grid for guiding a wire mesh between the rolls pivotally mounted above the rolls, and having its lower end between the orifice and the rolls and projecting down into the stream of glass passing from the orifice to the pass between the rolls.

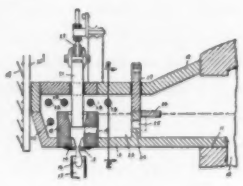


Ink for glass. MARK N. FREDENBURGH. U. S. 1,538,890, May 26, 1925. An ink suitable for printing on vitreous articles comprising a metallic oxide decomposable to produce an opaque metallic body, a low fusing point enamel and a vehicle containing only a small amount of residual carbon on decomposition.



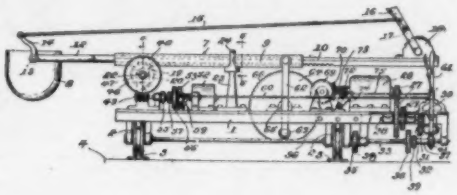
Apparatus for making reinforced glass. WILLIAM C. BULL. U. S. 1,539,239, May 26, 1925. An app. for fabricating reinforced glass including an oven-chamber, means for sealing a press therein for the glass product, means for supplying dry heat to the chamber while the glass product is under press. and means for exhausting air during the dry heat and press. period and for causing circulation of the heated air currents during the final stage of the dry heat and press. period.

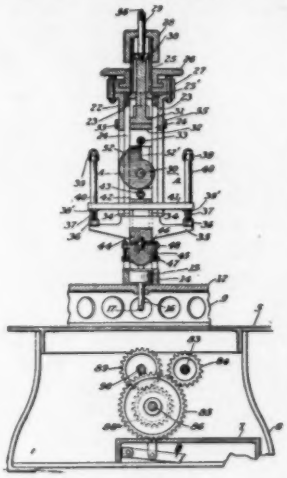
Electrically-heated glass-flow device. JOHN RAU. U. S. 1,539,598, May 26, 1925. In a continuous flow glass feeding trough, having a glass containing chamber therein, a high temp. relatively non-disintegrating elec. htg. means extending across the chamber and above the glass for directly htg. the same to high temps.



Glass-gathering apparatus. WILLIAM WESTBURY.

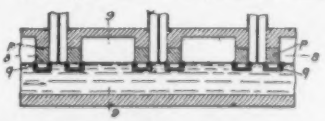
U. S. 1,539,707, May 26, 1925. In a gatherer of the character described, the combination of a carriage, a vertically tilting arm mounted on the carriage and comprising telescopic sections, one of said sections being pivotally connected with the carriage at a point between its ends and the other slidably engaging said pivoted section, said slidable section having rack teeth, a ladle carried by the sliding arm section, means including a gear mounted concentric with said pivotal connection and meshing with the rack teeth for sliding said sliding arm section in or out to advance or retract the ladle, and means coupled to said pivotally mounted arm section for tilting said arm in a vertical plane.

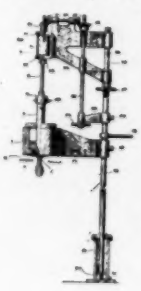




Machine for forming glass articles. CHARLES H. R. HOWE. U. S. 1,539,842, June 2, 1925. A mach. for forming glass articles comprising a supporting structure, a rotatable mold carrying table thereon, an annular series of molds on the table, means for intermittently rotating the table through a limited arc, a vertically reciprocable press coöperating with the molds for forming the articles as the molds are brought successively under the press, a rotatable cam and means engaging the cam for raising and lowering the press, said cam being so arranged as to enable the press to be lowered independently thereof when the cam is in a certain predetermined position. The combination with a glass article forming mach. comprising a supporting frame on which is mounted a rotatable table, a series of molds having vertically movable center portions on the table, means for intermittently rotating the table, a press coöperating with the molds, means for raising the central parts of the molds above the other parts after they have passed the press, of a rotating stripping means adapted to swing over the molds when the central parts are elevated having a pair of pivoted depending jaws on said stripping means for gripping the opposite edge of an article on said elevated mold and removing it therefrom.

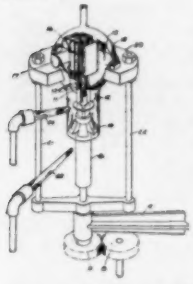
Furnace for use in the manufacture of sheet glass by vertical drawing. ERNEST DELACUVELLERIE. U. S. 1,541,906, June 16, 1925. An improvement in fur. for use in the manuf. of glass sheets by vertical drawing and consisting essentially in the addition of a homogeneous piece of refrac. mat. of suitable section which is placed directly under the bridge pieces proper which exist in this type of fur., the injurious corrosion of the joints of the usual bridge pieces being avoided and the particles or grains which become detached from the walls collecting on the said under additional pieces, the replacement of which additional pieces being effected without complete stoppage of the fur. and their protection assures perfect manuf. of the glass sheet without striations or cords.





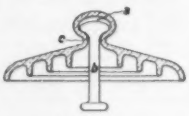
Plunger-operating mechanism for glass furnaces. THOMAS STENHOUSE. U. S. 1,542,013, June 16, 1925. A glass fur. including a flow

spout, a plunger adapted to reciprocate in said flow spout, means for reciprocating the plunger, and fluid press. operated means for lifting the plunger clear of the flow spout.



Glass working machine. JOSEPH BRANIGAN. U. S. 1,542,365, June 16, 1925. A mach. for sealing a stem in a bulb comprising a support for the stem, a support for the bulb, means mounted on said support for the stem, and surrounded by the bulb for maintaining the bulb in the desired relation to the stem, said means having a discontinuous surface whereby heat may be applied to the stem.

Method of making suspension insulators of glass. ERICH SCHOTT. U. S. 1,542,588, June 16, 1925. Method of making suspension insulators of glass, consisting in this that a glass body is first shaped in such a way as to receive a hollow space, adapted to receive a clapper, that thereupon a clapper is inserted and finally the glass is pressed round the clapper, so that after the hardening of the glass the said clapper cannot be pulled out from the said hollow space.

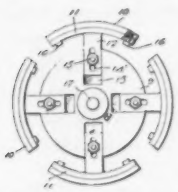


Heavy Clay Products

Preventing rust on drier cars. E. BUSS. *Sprechsaal*, **58**, 328–9(1925).—B. used mixts. of a silicate, cement, sand and clay to paint the Fe on drier cars and thus protect them from rusting. The silicate employed contained 65.54% SiO_2, 15.85% Al_2O_3 and 10.91% H_2O. One mixt. consisted of 85 cement, 9 silicate, and 6 clay. Another mixt. consisted of 1 cement, 2.5 sand, and a certain amount of silicate. H. G. S.

PATENT

Brickmaking machine. KENNETH G. MCMILLAN. U. S. 1,541,429, June 9, 1925. In a brick printing mach., the combination of a traveling clay bar from which the bricks are adapted to be cut, a printing member comprising a rotary carriage and a plurality of circumferentially arranged printing plates, the circumference of the printing member being predetermined to equal exactly the length of the bar necessary to produce bricks equal in number to the number of printing plates on the carrier and said plates being adjustable relatively to one another to vary the circumference of the printing member to compensate for variation in the length of bricks cut from the bar and means for utilizing the travelling movement of the bar to drive said printing member at a rate of speed equal to the speed travel of the bar.



Refractories

British comments on lime kiln refractories. ALFRED B. SEARLE. *Rock Products*, **28** [11], 49–50(1924).—The chief actions to which the refractory lining of a lime kiln is subjected are: (1) abrasion of descending charge of stone and lime; (2) sudden changes of temp.; (3) chem. action of the fuel; (4) chemical action of the lime. Paving bricks, hard fine textured fire bricks, granite and steel plate are used in the uppermost 6 ft. zone. In the fire zone high alumina fire brick are most satisfactory, in resisting the chemical action of the lime. Silica brick although used are not satisfactory. Magnesia brick do not withstand the temperature changes nor the resistance to abrasion. Rammed and tamped linings are not durable. Blocks are preferable to brick as there are

fewer joints. Insulation of a kiln saves fuel but increases the temperature of the inside wall thus necessitating a higher temp. refractory in the hot portion of the kiln.
H. G. F.

Dolomite as refractory material. T. N. LESLIE. *South African Jour. of Sci.*, **21**, 159(1924).—The object of this note is to call attention to the Transvaal dolomite as an economic factor in the development of industry in S. A., more particularly as a refractory material. Dolomite occurs over a great part of the Transvaal. Many analyses have shown nearly every gradation of the 3 first named between:

$CaCO_3$.....	54.46	and	9.07
$MgCO_3$.....	44.23	and	3.01
SiO_2.....	0.69	and	62.16

O. P. R. O.

Silica (New South Wales). L. F. HARPER. *Geol. Surv. Bull.*, **10**(1924).—Known deposits of material in New South Wales suitable for the manuf. of silica bricks are 2 types, and although analyses of bricks made from each of the 2 types of deposits are practically the same, the reactions to firing are very different. Bricks made from the Ulladulla deposits will *not* stand variations in temp., but they are said to be equal, if not superior, to any other silica brick for steel furnace works. The bricks made from the Marrangaroo quartzite are most suitable for furnaces at glass works, gas works, and other places where brick is subjected to var. in temp. It appears that New South Wales has silica suitable for manuf. of high-grade silica bricks adapted to all requirements.
O. P. R. O.

Corrosion of fire brick, silica brick, and magnesite brick, by furnace slags. J. PRELLER AND V. KORBER. *Chem. Listy*, **19**, 48–51(1925); *Jour. Soc. Chem. Ind.*, **44B**, 326(1925).—Basic slags corrode magnesite brick less than fire brick or silica brick, and the action is the less, the smaller the periclase crystals, the denser the brick, the smaller the SiO_2 content, and the slower it is cooled. SiO_2 favors formation of olivine, and this reduces the softening pt. of the brick. H. H. S.

Staining process for testing refractory materials. E. STEINHOFF AND F. HARTMANN. *Stahl u. Eisen*, **45**, 337–43(1925); *Jour. Soc. Chem. Ind.*, **44B**, 317–8(1925).—Staining after etching, well-known in petrology, is applied to refactories. The etching soln. consists of equal pts. concd. HCl and satd. $AlCl_3$. The gelatinized ingredients are stained with methylene blue. Clay fired up to 1000° is stained deep blue; at 1100°, light blue; at 1200° scarcely colored; and at 1300° colorless. Quartz unmodified by the treatment is colorless, while quartz modified is sky-blue. Clay-lime and clay-MgO zones are stained dark-blue, but they may be distinguished by staining with anthrapurpurin, which gives a typical red-brown with CaO ingredients. The staining test thus supplies data on: the temp. of burnt clays and clay-grog brick; the occurrence, distribution and degree of modification of quartz; localized CaO and MgO fusions; presence and position of thin layers of kaolin in quartzites; extent of modification in silica brick; and behavior of silicate fusions. H. H. S.

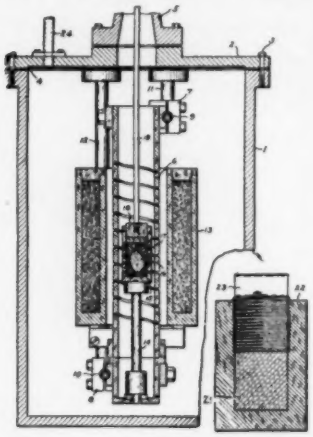
Attack of fire brick by combustion products. D. J. VAN WIJIK, JR. *Chem. Weekblad*, **22**, 16–8(1925).—The principal factor in the corrosion of refractory material of a furnace is the ash of the fire; high Fe or Al content of the fuel is particularly objectionable. Good fire brick should have an Al_2O_3/SiO_2 ratio as near to 71/29 (mullite, $3Al_2O_3 \cdot 2SiO_2$, according to Bowen and Greig), as practically possible, low Fe, Na, K and Ca content and low porosity. (*C. A.*)

PATENTS

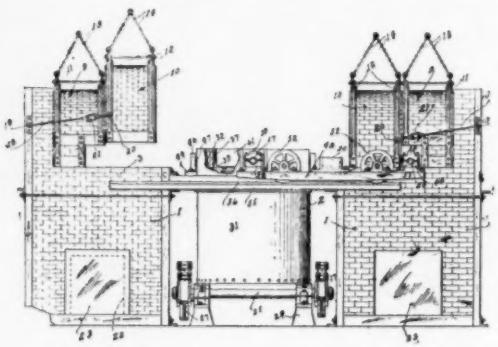
Process of manufacturing heat-insulating brick. RICHARD C. WILLIAMS. U. S. 1,540,509, June 2, 1925. That method of mfg. heat insulating refrac. bricks and the like which consists in mixing together diatomaceous earth, a combustible coking

binder and water, the quantity of diatomaceous earth being at least equal to the combined quantities of binder and water, molding the mixt. and exposing the molded mixt. to a heat sufficient to primarily drive off the volatile matter, next to coke the binder and finally to burn out the binder and effect sintering of the silica.

Process of making vitreous silica. LEVI B. MILLER. U. S. 1,541,584, June 9, 1925. The method of producing clear vitreous silica or quartz glass which consists in htg. quartz in the crystal state to a fusing temp. in a vacuum while mechanically supporting said quartz to prevent displacement of particles resulting from the cracking of said quartz when heated to a temp. of about 550°C.



Glass apparatus. ROBERT W. HILTON. U. S. 1,541,142, June 9, 1925. An app. of the class described, spaced draining furnaces open at their relatively adjacent sides, means for closing each fur., a drawing fur. located between the draining furs., a truck supported for travel between the draining furs. and with relation to the drawing fur., the truck including side sills spaced to span the respective draining furs. when the truck is at one or the other limit of its travel, bearings upon the sills, and pots having trunnions journaled in the bearings, the said bearings being of trough-like form whereby to contain a cooling fluid.



Whiteware

Manufacture of chemical apparatus from porcelain. E. MOSER. *Chem. App.* **12,** 73–4(1925).—Apparatus usually made of chem. stoneware can be made of porcelain, which has the advantage of lighter weight and longer life. Illustrations are given of stills, pumps, and large contg.-vessels. They are said to stand a press. of 1376 kg. per. sq. in., to have a modulus of elasticity of 8280 kg. per sq. mm., a spec. ht. 0.221, coeff. of expansion 0.0000038, m. p. 1670°, and softening pt. 1400°C. H. H. S.

Changes in porcelain in tunnel-kiln. E. KEMPCKE. *Keramos,* **3,** 551–7(1924); *J. Soc. Chem. Ind.,* **44B,** 318(1925).—Samples were taken from a tunnel-kiln after having been fired for periods varying from $22^1/_2$ to $31^1/_4$ hrs. at temps. varying from 1050° to 1420° in intervals of 25° to 60°. The course of porcelain formation, the interaction of the raw materials with each other, and the changes in porcelain structure were examined miscroscopically. The color and hardness of the body and glaze, the fracture, porosity and true and apparent d. were also detd. Between 1050° and 1160° the products were "dry" and non-translucent, like earthenware. Sintering began at 1180°, and at 1230° the ware was almost porcelainic. Formation of porcelain, with soln. of quartz and crystal formation, reached its max. at 1420°. H. H. S.

Ceramics at the Bureau of Standards. ANON. *Chem. Met. Eng.*, **10**, 423–5 (1925).—Describes the investigations at the Bureau in 1924, in the field of pottery. The work was mainly on specifications for vitrified tableware, and thermocouple protection tubes in glass furnaces. M. E. M.

Progressive porcelain plant producers' profits. ANON. *Ceramic Industry*, **4** [4], 287–90(1925).—This article contains a description of the plant and opern. of the Federal Porcelain Co., of Carey, Ohio. The plant is also well described pictorially. The product is low tension elec. insulators, which are made both by the dry press and plastic process. The clays are weighed on a scale car, blunged for 4 hrs., sieved, and filter pressed in 1 hr. and 15 mins. under a press. of 140 lbs. per sq. in. The ware is dried in humidity driers and fired to 2600°F in 30 hrs. in down-draft periodic kilns. The sagger clay is thoroughly weathered by keeping it sprayed with water for a considerable length of time. The saggers are mach. made and dried at 150°F for 12 hrs. The life of the sagger is 6 firings. P. D. H.

Sulphur models for molding ceramic molds. E. MOTSCHMANN. *Sprechsaal*, **58**, 323 (1925).—Sulphur models for making plaster molds offer advantages in some cases over plaster models. It cannot be used for models which require finishing and is best adapted to small models which are cast in 2-piece molds. In making a model of S the original shape is first molded with clay and then the mother mold is cast about this similar to the method employed for plaster models. The inside of the plaster mold is carefully finished and is coated with an oil instead of shellac. Three-fifths old S is mixed with $^2/_5$ new S and the mixt. is melted in an Fe pot. When the S has become thoroughly melted about $^1/_3$ Fe filings or Fe scale are added. The molten S is then poured in the plaster mold where it is allowed to remain until is has become thoroughly solidified. In casting a plaster mold from this S model it is covered with a fatty oil contg. some petroleum. S models are much more durable than plaster models and also have the advantage in that the old models may be remelted and used over again while plaster models cannot be used again. H. G. S.

Testing and research fields of high tension insulators. ANON. *Sprechsaal*, **58**, 322–3(1925). H. G. S.

Insulating materials. K. G. MAXWELL AND ALLAN MONKHOUSE. *Quarry and Surveyors' and Contractors' Jour.*, **30**, 123(1925).—A paper given before the Institution of Electrical Engineers (England) reviewing recent developments in the manuf. of insulating materials, with data obtained by the test methods as adopted by the Elec. Research Assn. including tables showing properties of the principal insulating mats. The following gives the elec. strength in V/mil. of various fireproof and refrac. materials: porcelain (wet method), 150–200; porcelain (dry method), 80–120; marble, 40–80; slate, 5–20; heavily spotted green mica, 1100; medium spotted green mica, 1200; medium spotted brown mica, 2000; clear ruby mica, 2250; clear brown mica, 3500; Canadian amber mica, 3800; clear white (Muscovite), 3000; Port. cement and asbestos molded compositions, 5–50 (at 20°C). O. P. R. O.

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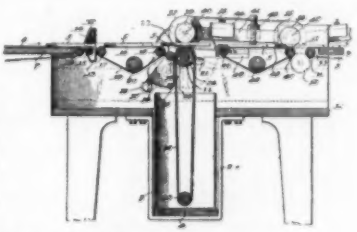
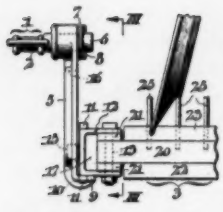
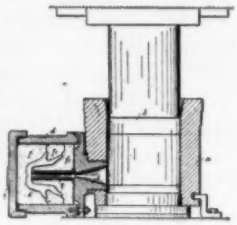


Glaze machine. JOHN B. OWENS. U. S. 1,540,417, June 2, 1925. In a mach. for glazing tiles, the combination with means for applying the glaze to the tiles, of an endless apron for delivering the tiles to said glazing means, means for cleaning the tiles before they pass to the endless apron, and another endless apron to which the glazing means delivers the tiles after they have been glazed, said last named apron removing the glazed tiles.



Device for supporting chinaware or the like during the process of manufacture. THOMAS ALLSOP. U. S. 1,539,808, May 26, 1925. In an app. of the character described a reversible tray adapted to support the articles to be dried in either of its positions, said tray being provided with means for supporting said articles on edge.

Process for the production of ceramic ware. RICHARD SPRENGER. U. S. 1,541,869, June 16, 1925. A process for the manuf. of ware from ceram. mat. and especially porcelain, consisting in applying press. upon a mass of ceram. mat. within a container while the said mat. is in a plastic and non-fluid condition, extruding thereby a portion of the said mass from the container through an inlet into a mold, which inlet extends through a part of the mold into a position when the extended mat. is distributed to fill the molding space, substantially as described.



Equipment and Apparatus

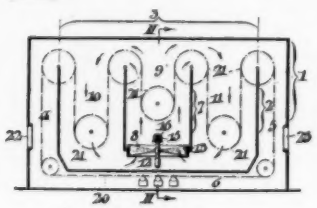
An optical pyrometer. IAN STEWART. *Chem. Eng. Mining Rev.*, **17**, 275–6 (1925).—Describes a new radiation pyrometer in use in Australia. The instrument is self-contained, fits in the hand, and is used like a telescope. M. E. M.

Apparatus for measuring the warpage of tank and floor tile. O. KALLAUNER. *Sprechsaal*, **58**, 321–2(1925).—K. describes an apparatus for measuring the warpage on square tile. The tile are set on a square table which is carefully leveled and the warpage at any portion of the tile is measured by means of a needle. H. G. S.

Electric power in the brick industry. T. R. C. FLINT. *Contract Rec. and Eng. Rev.*, **39**, 385(1925).—The advantages of electricity in the operation of a brick plant and the power required for various processes were discussed in an address by F. of the Toronto Hydro-Elec. System before the Sand-Lime Brick Assn. in which he points out that the use of electric power split up into one and more units, the proprietor of the plant is able to take advantage of the diversity factor in the load and thus cut down power costs as compared with a steam engine installation. If for any reason central station power is not available, very efficient and compact generating stations can be installed. A number of brick plants have installed steam driven elec. plants in order that the flexible elec. motor drive may be used. O. P. R. O.

Thermostats for very high temperatures. LEASON H. ADAMS. *J. Optical Soc. Am.*, **9**, 599–603(1924).—The heating coil of the elec. fur. forms one coil of a wheatstone bridge. Changes in temp. unbalance the bridge and actuate a current controlling mechanism of which a description is given. D. E. S.

A centrifugal pump for handling liquids carrying hard, abrasive materials. T. HOFFMANN. *Chem. App.*, **12**, 62–3(1925); 2 cuts.—The housing has a renewable steel lining. (*C. A.*)

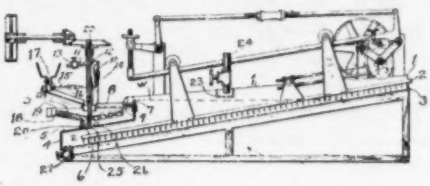


PATENTS

Apparatus for drying or otherwise treating manufactures. THOMAS ALLSOP AND WALTER W. SIBSON. U. S. 1,539,807, May 26, 1925. App. of the character described comprising an enclosure; a U partition therein; and radiators within said partition.

Closed-circuit classifier. ROLLAND S. TROTT. U. S. 1,541,237, June 9, 1925. A classifier unit,

comprising in combination, a thickener and a classifier, each provided with an overflow, the classifier having an outlet above its liquid level, a device for moving settled mat. to said outlet and an aperture below its liquid level, the thickener having a bottom surface adapted to receive settling mat., and being provided with a discharge orifice and with a device for moving settled mat. toward said orifice, means joining the thickener and the classifier so that said orifice registers with said aperture, means for feeding mat. to the thickener, means for feeding a liquid to the classifier, and means for conveying the overflow from the classifier to the thickener.



Kilns, Furnaces, Fuel and Combustion

Fuel economy obtained by air preheating. MARCEL ESBRAN. *Tech. moderne*, **17**, 235–6(1925).—A mathematical discussion showing that by preheating the air used for combustion, a given temp. can be maintained in the furnace with a decrease in fuel consumption equal to about 7% for an increase of 150° in the temp. of the air and for 1400–1500° in the furnace. *(C. A.)*

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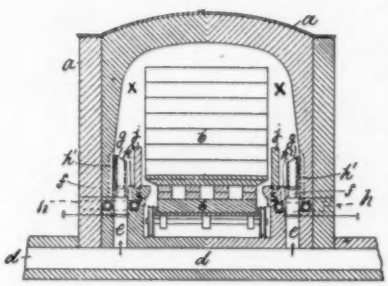
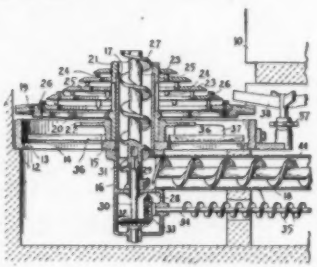
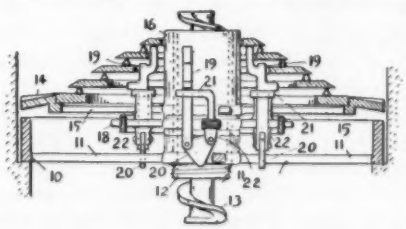


Gas-fired oven or kiln. JOHN HENRY MARLOW. U. S. 1,541,647, June 9, 1925. In a tunnel kiln, means for htg. the same by gaseous fuel, comprising a transverse flue which is connected with a gas supply, gas supply openings between the flue and vertical burner tubes which communicate with the gas supply, ways having outlet openings on different horizontal planes for supplying air about the burner tubes, and a wall which extends vertically above the open upper ends of the burner tubes.

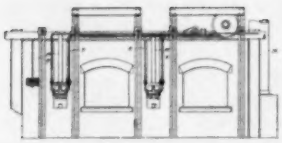
Furnace. JOHN D. MARTIN. U. S. 1,541,648, June 9, 1925. In a fur. a conical grate, an underlying ash-ring, a scraper with radiating arms for removing ashes from the ash-ring, and means for revolving the ash-ring and the scraper.



Furnace grate. JOHN D. MARTIN. U. S. 1,541,649, June 9, 1925. In a fur. a conical grate consisting of a series of superimposed rings, means for revolving the grate, lifting elements carried with the revolving grate for separating the rings, and stationary elements which are engaged by the lifting elements.



Furnace. CLARENCE E. HAWKE and BOYD M. JOHNSON. U. S. 1,542,552, June 16, 1925. A fur. comprising a htg. chamber having a combustion chamber associated



therewith, a pre-heating chamber, a pair of flues beneath the floor of said pre-heating chamber and each having its top wall formed thereby, said top walls having openings therein establishing communication between said flues and pre-heating chamber, and means for conducting the waste gases from said combustion chamber to one of said flues and for conducting them from the other of said flues out of the fur., substantially as described.

Geology

Cryolite (Greenland). ANON. *Indus. Australian & Min. Stand.*, **23,** 162(1925).—The world's only cryolite quarry. Cryolite occurs in commercial quantities only in Greenland, at Ivigtut. It is mined in a great open cut, the vertical walls of which stand remarkably well. Air drills are used, and the cryolite is shot with black powder down in benches from the top, the effort being to shatter the product as little as possible. Three classes are produced, one for the U. S., the black (dark brownish-grey translucent) cryolite, which contains approx. 93% of cryolite; and two for Denmark, both white, said to be 95% and 99% pure. Of the cryolite shipped to the U. S. the greater part is now used as a flux in the metallurgy of aluminium and for opaque glass. In aluminium metallurgy the mineral is rapidly being supplanted by artificial cryolite.

O. P. R. O.

Graphite deposits of Ashland, Alabama. J. S. BROWN. *Econ. Geol.*, **20,** 208–48 (1925). H. H. S.

The chemical composition of the earth. H. S. WASHINGTON. *Amer. J. Sci.*, **9,** 351–78(1925).—The composition of the whole earth, core and crust, is: Fe (Metal) 31.82%, Fe (Silicate) 7.94, O 27.71, Si 14.53, Mg 8.69, Ni (Metal) 3.16, Ca 2.52, Al 1.79, S 0.64, Na 0.39, Co (metal) 0.23, Cr 0.20, K 0.14, P 0.11, Mn 0.07, C 0.04, Ti 0.02%. Goldschmidt's Sulphur-oxide intermediate Zone is not accepted. From the core upward the shells are called lithosporic, ferrosporic, peridotic, basaltic, and granitic.

H. H. S.

Phosphate deposits of the Pacific. F. D. POWER. *Econ. Geol.*, **20,** 266–81(1925). H. H. S.

Occurrence of diaspore in the Transvaal on Mooikopje, 58, Middleburg. A. W. ROGERS. *Trans. Geol. Soc. S. Africa*, **27,** 71–5(1924).—Analyses of kaolinite and diaspore are given. (*C. A.*)

BOOK

Engineering Geology. H. RIES AND T. L. WATSON. 697 pp. 253 figs. New York: John Wiley & Sons, 1925. $5.00.

Chemistry and Physics

A method of preparing thin sections of friable rocks. CLARENCE S. ROSS. *Amer. Jour. Sci.*, **6,** 483–5(1924).—On heating bakelite varnish a transformation takes place producing bakelite. By impregnating friable rocks and mats. such as bentonite or clay with bakelite thin sections can readily be prepared of such mats. The most practical method of impregnating is to soak the specimen in the varnish, allowing the varnish to fill the pores by capillary attraction. Bakelite varnish is soluble in alcohol and ether, with which it may be diluted in order to make it penetrate more readily into fine pores. After soaking the fragment it is heated one or two days at from 70° to 90° in order to transform the varnish to bakelite. Bakelite is not softened by heat. To avoid the formation of bubbles the varnish may be heated to drive off a portion of the volatile

matter, but not to hardness. This pre-heated mat. is superior for use as a cement. The index of refraction of bakelite is 1.634. In mounting friable rocks it is suggested to impregnate the rock with bakelite, and after grinding down one face to mount the specimen to the slide with balsam, using balsam for the cover slip. The high index of bakelite makes it desirable as an imbedding medium for certain mats. that have a high indices of refraction. H. G. F.

Equations of state of the plastic phase of a natural isotropic solid. M. BRILLOUIN. *Sci. Abst.*, **28** [4], 263(1925); *Compt. Rend.*, **179,** 1563–6(1924).—The solids commonly termed malleable or ductile present two phases according to the forces exerted upon them, *viz.*, an elastic one with sensibly reversible properties, and a plastic phase. The author now develops a theory for the latter analogous to the theory of elasticity. He questions the validity of the isotropic theory and substitutes one which is in best accord with observations, *viz.*, that the plastic phase is characterized by the fact that only one of the six elements of deformation is free to increase indefinitely, while the other five continue to be determined by elastic conditions. If the unique deformation does not produce a change of density, the phase is plastic, otherwise it is brittle. Based on this hypothesis, equations of state are derived which characterize the plastic state and rectify the equations of Levy derived from the old hypothesis. A. F. G.

Ring method of measuring surface tension. P. E. KLOPSTEG. *Sci. Abst.*, **28** [4], 260(1925); *Science*, **60,** 319–20(1924).—The author points out that the values given for the surface tension of water measured by the ring method are on the average 3.2 dynes per cm. greater than the mean value given by other methods. Fahrenwald's explanation of this difference is discussed, and shown to be probably incorrect. The author considers that the error was probably a systematic one, due to some faulty technique, and the following explanation is suggested: As the ring is drawn out of the liquid, the upward force on the ring, measured by the torsion of the wire, is just balanced by the weight of the liquid elevated above the normal surface. It is important to note that the scale readings of the instrument are taken with reference to the scale zero, and that the scale zero corresponds with the actual zero of torsion only when the arm which carried the ring is in its position of zero balance. As the ring is pulled higher with increasing force, the true zero on the scale, with reference to which reading should be taken, shifts upward from the scale zero by an amount which corresponds to the position of the arm. Consequently, at the instant the film ruptures, the scale reading will be too high. A new technique has been devised whereby the vessel containing the liquid is gradually lowered, by means of the screw adjustment on the support, while the increasing force is being applied, all the while maintaining the arm in its position of zero balance. Experiments to test this explanation have shown a difference of 3.3 dynes per cm. for water when the old technique and the new technique, respectively, were employed. A. F. G.

Note on the viscosity measurement of ceramic bodies. O. KRAUSE. *Sprechsaal*, **58,** 230(1925).—K. discusses the advantages and disadvantages of the Fischer Bauer ball viscosimeter. K. obtained good results for plant control work by using a 200 cc.-pipette for measuring the viscosity of clays by the flow method which gives comparable results but does not give the actual viscosity of the slip. H. G. S.

Silicate solutions and some siliceous gels. J. G. VAIL. *Jour. Soc. Chem. Ind.*, **44,** 214–9T(1925).—Soluble silicates have in recent years assumed a steadily increasing importance in industry. Films of gel, formed in hot water supply systems by introducing small amts. of sodium silicate of a type high in SiO_2, prevent corrosion of metal piping. Plumbo-solvent-moorland waters, treated with 5 pts. per 10^6 of SiO_2 as sol. silicate, are changed from a menace to health to a condition of safety. Dry batteries made from Zn which had been cleaned with silicate soln. corrode more evenly in service than the

same metal cleared with other alk. solns. Films on metal coats are the best foundation for paint coats. The cause of film formation has not been fully explained, but it is noted that negatively charged colloidal particles of SiO_2 are capable of absorbing + ions upon their surface, and that at each surface where film is formed positively charged metallic ions are known to exist. Commercial sodium silicate solns. contain 1.5–4.2 mols. SiO_2 for each Na_2O; they are regarded as contg. the more or less dissociated metasilicate, Na_2SiO_3, and colloidal SiO_2. Anything which tends to remove the Na ions from its relation to the SiO_2 particles will induce gelation, *e. g.*, CO_2, acid salts, alcohol, NH_3. The industrial use of silicate depends on this fact. H. H. S.

The scratch test for hardness. G. A. SHIRES. *Engineering*, **119**, 557(1925).—A sclerometer consisting of a diamond with a load of 50 g. was compared with the Brinell test for steels. The relation is as follows:

Width of scratch in μ	Brinell hardness	Width of scratch in μ	Brinell hardness
29	203	22	430
28	230	21.5	453
27	240	21	494
24.5	320	20.5	517
24	346	20	585
23.5	363	19.5	625
		19	653

H. H. S.

Action of fluxes on ceramic raw materials. K. G. VERSHOFEN. *Keramos*, **3**, 451(1924); *J. Soc. Chem, Ind.*, **44B**, 318(1925).—Of the 4 chief raw materials, clay, kaolin, feldspar and quartz, quartz was the only one really attacked at 1000° by basic Ca, Mg and Na compds. and by soluble fluorides. The action on quartz depended on its fineness. H. H. S.

Reactions of chromates at high temperatures. M. R. NAYAR, H. E. WATSON, AND J. J. SUDBOROUGH. *J. Indian Inst. Sci.*, **7**, 53–70(1924).—$CaCrO_4$ gives off O at 1000°. Addn. of CaO lowers temp. of decompn., 0.1 mol. CaO lowering it to 800° but decompn. is not complete even at 1300°. There is no evidence of the formation of definite compds.; a series of solid solns. appears to be formed. If the same molecular mixts. as above are made up from CaO and Cr_2O_3 the same per cent chromate is obtd. at each temp., chromate formation beginning at 600° and proceeding more rapidly with excess CaO. Na_2CrO_4 may be heated to 1000° without decompn.; $MgCrO_4$ is almost completely decomposed at 650° yielding chromites. Na_2CrO_4 can be made almost quantitatively from Na_2CO_3 and Cr_2O_3 in 4 hrs. at 755°; $MgCrO_4$ is formed very slowly from MgO and Cr_2O_3 at temps. below 600°. H. H. S.

Studies in the mica group. A. N. WINCHELL. *Amer. J. Sci.*, **9**, 309–27, 415–30 (1925).—The theory that valence determines what elements can take the place of others in an isomorphous series of crystals of complex compn. is discarded. So long as all valences are satisfied in each mol., one element can replace another if the atoms are similar in volume. In micas, as in other silicates, each crystal is an aggregate of several intergrown space-lattices which differ decidedly in the size of their atoms. Micas are not orthosilicates, nor metasilicates, nor any other single type of silicate. There are two classes of micas, one characterized by 7 atoms (excluding O, H and F), and the other by 8 atoms. The first class, named heptaphyllite, contains muscovite KAl_2Si_3, polylithionite KLi_2Si_3, phengite KAl_2Si_4, protolithionite $KFe_{1.5}Al_2Si_{2.5}$; and micas contg. more than one of these mols., *e. g.*, lepidolite, which is $Mus_{50}Pol_{50}$, Zinnwaldite $Lep_{50}Pro_{50}$, and mariposite $Phe_{50}Pro_{50}$. The class contg. 8 atoms is named octophyllite and consists of the biotite group. The variations imply the existence of 4 chief mols.: phlogopite

KMg_3AlSi_3, eastonite $K_2Mg_5Al_4Si_8$, siderophyllite $K_2Fe_5Al_4Si_8$, and annite KFe_3AlSi_3. Haughtonite is $Es_{50}Sd_{50}$. In general, octophyllite is dark and heptaphyllite light-colored, but this distinction is not reliable. Several black micas have been called biotite which are heptaphyllite, while colorless mica may be octophyllite. H. H. S.

Density, porosity and occluded gases of clays, kaolins and light silicas. A. BIGOT. *Compt. rend.*, **180,** 666–8(1925).—The origin of diatomaceous earth and infusorial earth is known but that of the globular SiO_2 is not. An infusorial earth of Ouillis (*a*) and a globular SiO_2 of Mesnes (*b*) contained, resp., SiO_2 88.30, 87.95; Al_2O_3 0.99, 3.10; Fe_2O_3 1.01, 1.05; CaO 0.30, 0.10; MgO 0.07, 0.90; P_2O_5 0.01, —; loss on ignition 8.80, 6.80%. The SiO_2, purified by levigation, gave a soft mass, that from (*a*) having an apparent d. of 0.61 and that from (*b*) 0.72. The powd. materials themselves showed great differences in apparent d. (*a*) 0.160 and (*b*) 0.425. There is no relation between chem. compn. and apparent d. Subjecting a powd. sample of (*a*) to a pressure of 100 kg. per sq. cm. and evacuating to 2 mm. Hg drives out most of the air, which is absorbed again when the pressure and vacuum are removed. Absolute d. is detd. in a sp. gr. bottle, with petroleum for liquid. The sample is first dried for 2 hrs. at 120°. It takes 1–2 days for all bubbles to be removed by the vacuum. Absolute d. of (*a*) is 2.32. The powder whose apparent d. was 0.160 contained 6.89% SiO_2 and 93.11% gas. The sample whose apparent d. was 0.61 contained 26.29% SiO_2 and 73.71% gas. A sample of 100 cc. of soft paste of (*a*) weighed 130 g. and lost 65 g. in drying. This sample, then in the soft state, contained 65 cc. of H_2O and 28 cc. of SiO_2, leaving 7 cc. (or 7%) of air. Clays and kaolins show the same properties in varying degrees. The proportion of occluded gas in clays decreases as the colloidal plasticity increases. The methods have been applied also to a number of rocks, glasses, porcelains and other materials often considered impermeable. (*C. A.*)

The effect of gases on silicates. HANS V. WARTENBERG. *Z. anorg. allgem. Chem.*, **142,** 335–6(1925).—Quartz-glass and porcelain are attacked by H at temps. of 1200° and above with formation of Si vapors, which under certain conditions condense to brown Si (*C. A.*, **7,** 1451). In the presence of metals the Si is dissolved. H_2O seems to react with the FeO of the porcelain at 1200° as O disappears (Nernst and v. Wartenberg, *Z. physik. Chem.*, **1905,** 535). Cl reacts with the Fe_2SiO_4 of the porcelain at 600° with the formation of $FeCl_3$. (*C. A.*)

The entrainment of magnesium by calcium oxalate. LEMARCHAND. *Compt. rend.*, **180,** 745–8(1925).—As a result of some 134 analyses it is shown that the presence of MgC_2O_4 in a ppt. of CaC_2O_4 is the result of 2 factors. (1) In a soln. which is not supersatd. with MgC_2O_4, there is some adsorption. Thus, when about 0.02 g. of Mg is present in 200 cc. of soln. contg. 0.2 g. of Ca, it is found that only 1.5 mg. of MgO is present in the oxalate ppt. This quantity is independent of the time that elapses before filtering. (2) Since only 0.06 mg. of MgC_2O_4 is sol. in 200 cc. of water, it is evident that in many cases the soln. is really supersatd. with MgC_2O_4 which deposits very slowly. Consequently, the often observed fact that the amt. of MgC_2O_4 pptd. with CaC_2O_4 in the ordinary course of analysis increases with the time that the soln. remains in contact with the ppt. is due to the gradual pptn. from a supersatd. soln. and not, as Richards and others have stated, to the fact that the ppt. slowly adsorbs MgC_2O_4. (*C. A.*)

Rapid determination of sulphur. FR. KÜHL. *Z. anal. Chem.*, **65,** 185–6(1924).—By taking 0.2 g. of S, boiling it with 50 cc. of *N* NaOH, adding 5 cc. of perhydrol and then titrating the excess NaOH with *N* HCl it was found possible to obtain results which were within 0.5% of the values obtained by much more tedious oxidation and pptn. methods. $S + 2NaOH + 3H_2O_2 = Na_2SO_4 + 4H_2O$. (*C. A.*)

Some new methods for the measurement of thermal conductivity. T. BARRTAT AND R. M. WINTER. *Phil. Mag.*, **49,** 313–23(1925); cf. *C. A.*, **9,** 2345. (*C. A.*)

Methods of obtaining an insight into the structure of ternary systems. W. GUERTLER. *Forschungsarbeiten zur Metallkunde*, **1923** [1], 19 pp.; *J. Inst. Metals*, **32**, 537–8.—A description is given of the method of building up the diagram of a ternary system from a knowledge of the equilibria in the 3 binary systems involved, and it is shown how the ternary system itself may be split up into 2 or more binary systems in cases where compds. are formed between 1 or more pairs of the constituents. Two generally applicable rules are formulated: (1) In those systems in which binary compds. are formed only between 1 pair of the constituents, mixts. of these compds. with the third constituent behave like binary systems (the so-called quasi-binary systems), and it is possible to divide the whole triangular diagram into a no. of smaller triangles without carrying out any expts. (2) If 2 elements *A* and *B* form no compds. with each other, but each forms 1 or more compds. with a third element *C*, then the compds. of each element richest in *C* are in equil. with each other and form a quasi-binary system. These laws are illustrated by descriptions and diagrams of the equilibria in the systems Ag–Pb–Sb, Ni–Pb–Sb, Pb–Cu–S, Mg–Zn–Al and Ni–Sb–S. (*C. A.*)

Data of geochemistry. F. W. CLARKE. U. S. Geol. Survey, *Bull.*, **770**, 841 pp. (1925); cf. *C. A.*, **15**, 3059.—The fifth edition. "Not an exhaustive monograph upon geochemistry, but rather a critical summary of what is now known, and a guide to the more important literature of the subject." (*C. A.*)

A determination of the melting and transition points of potassium dichromate. P. L. ROBINSON, G. E. STEPHENSON AND H. V. A. BRISCOE. *J. Chem. Soc.*, **127**, 547–9 (1925).—The m. and transition points of $K_2Cr_2O_7$ were redetd. by the cooling-curve method, with a Pt resistance thermometer, and found to be 398.4° and 236.8°, resp. (*C. A.*)

Some previously unknown properties of simple compounds, and remarks on the kinds of solid states. ERNST FRIEDERICH. *Z. Physik*, **31**, 813–27(1925).—The m. p. in degrees abs. of the following substances are: TiN, 3200; ZrN, 3200; VN, about 2320; CbN, about 2320; TaN, about 3070; ScN, about 2920; TiC, 3400–3500; ZrC, 3400–3500; V_2O_3, 2240; VC, 3100; Mo_2C, 2500–2600; MoC, 2840; WC, 3150. TiN, ZrN, TiC, ZrC and VC are stable at the m. p.; the other compds. dissociate somewhat. The following elec. resistivities were measured, the units being ohms per mm.^{2}: CuBr, 18,000; CuI, 13; ZnO, 1.8×10^{10}; CdO, 47; Tl_2O_3, 47; Ce_2O_3, ∞; SnO, 1.5×10^8; V_2O_3, 55; V_2O_5, 31,000; Cb_2O_3, 860; Cb_2O_5, 11.4×10^6; Ta_2O_5, 100; Ta_2O_5, ∞; Bi_2O_3, 1.2×10^8; MoO_3, 7.8×10^{10}; Mo_2O_5, 9.5; MoO_2, 40; WO_3, 1.8×10^9; W_2O_5, 4.56; WO_2, 9.8; UO_2 (blue), 30,000, (brown), 26.5×10^6; U_3O_8, 42×10^6; Ni_2O_3, 5.2×10^8; Co_2O_3, 194,000; Co_3O_4, 240,000; CoO, ∞; WS, 8.6; TiN, 1.3; ZrN, 1.6; VN, 2.0; CbN, 2; ScN, 3.08; TiC, 1.8–2.5; ZrC, 1.56; VC, 1.5; CbC, 1.75; TaC, 1–2; Mo_2C, 0.98; MoC, 0.49; WC, 0.53; SiC, ∞. The resistivities of the carbides and nitrides were also measured for the melts. F. classifies cryst. solids in the following groups: Noble-gas lattice, electrons not involved, example solid A; mol. lattice, electrons involved in holding atoms together to form a mol. but not involved in holding mols. together, example solid CO; ion lattices, example NaCl, show electrolytic condy.; atom lattice without condy., example SiC; atom lattice with a free valence electron, example metals and MoC; atom lattice with concd. due to kernal electrons, examples CdO, PbO_2; atom lattices with both types of condy., examples Pb and Tl. (*C. A.*)

The thermal expansion coefficient of crystalline substances. YOSITOSI ENDŌ. *Rept. Aeronautical Res. Inst. Tokyo Imp. Univ.*, **1**, 225–43(1924).—The mechanism of thermal expansion of cryst. substances and the variation is elucidated upon the ground of Born and Lande's theory (*C. A.* **18**, 1942) and the quantum theory. The involved formula for the expansion coeff. is $\alpha = (K\gamma/3v)(dE/dT)_p$ where K is the compressibility, γ is a const. related to the force function, v is the vol. per mol. and E is the energy

of thermal oscillation per mol. For metals $K = 9\delta^4/(nx - 1)a$, where δ is the length of side of the unit cryst. cube, a is the Madelung const. and n is a const. or repulsion. The value of a comes out $13.94e^2$ for face-centered lattices, showing that the no. of electrons equals the no. of atoms (a lattice of + ions and electrons); it is $47.8e^2$ for body centered lattices or the no. of electrons is twice the no. of atoms; it is $59e^2$ for diamond, which like ZnS, must show 2 lattices, one with $+ 4e$ and one with $-4e$ per atom. (*C. A.*)

Isomorphism of stannous and lead oxides. G. R. LEVI. *Nuovo cimento*, **1**, 335–44(1924).—SnO has a tetragonal structure with a c/a value of 0.895, which is inconsistent with the existence of a cubic form, at least under the conditions of prepn. described. PbO in the red form has a structure analogous to that of SnO. The c/a value is 0.90, which establishes the isomorphism of the two. The following represents a summary of an extended series of measurements:

	a	c	c/a	Density		
SnO	5.33 A.	4.77 A.	0.895	6.53	$\frac{a\ \text{PbO}}{a\ \text{SnO}} = 1.041$	$\frac{c\ \text{PbO}}{c\ \text{SnO}} = 1.048$
PbO	5.55 A.	5.00 A.	0.90	9.51		

(*C. A.*)

Molecular symmetry in crystal structure. J. H. SMITH. *Nature*, 334–5(1925).—S. detd. the cryst. structure of K salts, using the ionization spectrometer. $KClO_3$: monoclinic, and similar to NaCl. The edges of the half-mol. parallelopipedon are 3.56, 3.69 and 3.69 A. $KBrO_3$ ditrigonal, pyramidal, pseudocubic, body-centered, like CsCl. The edge of the 1 mol. pseudocube is 4.46 A. KIO_3: monoclinic, pseudocubic CsCl type, 1 mol.-parallelopipedon of edges: 4.57; 4.50; 4.50 A. From the similarity between simple (NaCl) and complex-radical salts ($KClO_3$), S. concludes that the symmetry is independent of the position of the atoms in the radical. This confirms the relationship pointed out by Clark (*C. A.* **17**, 2068). (*C. A.*)

Allotropy of the sesquioxides of iron, chromium, and aluminium. GEORGES CHAUDRON AND HUBERT FORESTIER. *Compt. rend.*, **179**, 763–6(1924).—Curves are given showing the differential expansion, with respect to a standard substance, of compressed rods of Fe_2O_3, Cr_2O_3 and Al_2O_3 (Chevenard's method, *C. A.* **15**, 1008). These oxides, when prepd. by desiccating the hydroxide at low temp., undergo a transformation at 400°, 500° and 600°, resp., which is accompanied by the evolution of heat and incandescence, and which ruptures the compressed rods. Therefore, they were made of oxide previously calcined at 1000°. The coeff. of expansion of Fe_2O_3 increases progressively with the temp. and passes through a max. at 680°. Fe_3O_4 shows a similar anomaly of expansion at 570° (Chevenard, *C. A.* **15**, 1645). It is suggested that the disappearance of the ferromagnetism of Fe_2O_3 may coincide with the change which occurs at 680°. If the rods of Fe_2O_3 and Fe_3O_4 are cooled rapidly by quenching, the curves indicate a contraction at 400° and 500°, resp., but return to the normal curve at 600° and 550°, resp. The curves for calcined Al_2O_3 and Cr_2O_3 are regular, presenting none of the anomalies of Fe_2O_3. The coeff. of magnetization of calcined Cr_2O_3 is 3 times less than that of the unstable oxide detd. before calcining. That of unstable Fe_2O_3 is 20 times greater than that for calcined Fe_2O_3. (*C. A.*)

First report on heat insulators. EZER GRIFFITHS. *Dept. of Sci. and Ind. Research, Fuel Investigation Board, Special Report*, No. **5**, 1–53(1924).—A new app. has been devised for measuring the insulating value of cork, cement, rubber, etc. The results of the measurements and of the calcd. thermal conductivities are given in detail. (*C. A.*)

Saturation capacity of clay soils. D. J. HISSINK. *Z. Pflanz. Düng.*, **A4**, 137–58 (1925); *J. Soc. Chem. Ind.*, **44B**, 293(1925).—Methods for detn. of saturation capacity and degree of satn. are given. Results are recorded of a number of such determinations,

and their bearing on the state of flocculation of the solid colloids, the pH value of the soil, and the lime requirement, is discussed. A close relationship is indicated between degree of saturation and the propn. of replaceable Ca present represented as a percentage of the amt. of clay. Conductometric measurements of equiv. wts. of humus and clay give values of 18 and 115, respectively, although rather wide fluctuations occur with clay. H. H. S.

BOOK

Zsigmondy Festschrift. Ed. by W. Bachmann and Wo. Ostwald. Pp. 390. Dresden: Theodor Steinkopf, 1925. Price, 20 m. A graceful tribute, in the form in which the Germans excel, to the well-known authority on colloids. H. H. S.

PATENTS

Manufacture of magnesia from dolomite. Camille Clerc and Armand Nihoul. U. S. 1,541,116, June 9, 1925. The process, which comprises calcining dolomite at a temp. above that necessary for decarbonation and sufficiently high to make hydration of the magnesia difficult without preventing hydration of the lime, swelling the lime-magnesia mixt. without completely hydrating the lime or dissolving the same separating the powder thus formed from the non-hydratable portion, and mixing the powder obtained with an excess of magnesium chloride to rapidly ppt. the partially hydrated magnesia in a readily filterable granular form.

Magnesium extraction. Brodde E. F. Rhodin. U. S. 1,539,955, June 2, 1925. The process of extracting magnesium from magnesium alloys which comprises treating such alloys in a bath of molten alkali having chem. affinity for the metal or metals with which the magnesium is alloyed and for which the magnesium has a natural chem. neutrality.

Process of recovering titanic oxide from titanium-nitrogen compounds. Peder Farup. U. S. 1,539,996, June 2, 1925. The process of recovering titanic oxide from titanium nitrogen compds. which comprises mixing the compound with a quantity of sulphuric acid not materially exceeding that required to combine with the constituents of the compd. other than titanium and htg. the mixt. in excess of atmospheric press. whereby the titanium contents of the mat. is obtained as an insoluble ppt. while its impurities as well as its iron and nitrogen contents are obtained as water sol. sulphates.

Preparation of magnesium carbonates. Soma Gelléri. U. S. 1,540,391, June 2, 1925. The herein described process for the production of magnesium carbonate from magnesium carbonates and magnesium silicates containing calcium, which consists in calcining the minerals contg. calcium and magnesium carbonates, then finely grinding the same and mixing with alkali metal-carbonates, dissolving in water, saturated with carbon dioxide, and htg. to from 60° to 70°C, separating the soln. containing the magnesium with the alkali metal as a double carbonic acid salt from the pptd. calcium carbonates and from the other solid residues, and subsequently decomposing by heat into insoluble magnesium carbonate and alkali metal carbonate remaining in soln.

Art of making zirconium compounds. Lonnie W. Ryan. U. S. 1,540,425, June 2, 1925. The method of prepg. granular basic zirconium sulfate which comprises adding sodium chloride to an aqueous zirconium sulphate soln. and subsequently adding an alkali thereto. See *Ceram. Abs.*, **4** [5], 135 (1925).

Process for obtaining magnesia from dolomite. Edgar Everhart. U. S. 1,542,-684, June 16, 1925. That method for obtaining magnesia from dolomite which consists in first reducing the dolomite to drive off the carbon dioxide, slaking the reduced dolomite, introducing acetic acid to neutralize the lime, separating out the calcium acetate and treating the residual magnesia mass separated from the lime with carbonic acid whereby to dissolve only the magnesia.

General

Sillimanite mine discovered in India. ANON. *The Glass Industry*, **6** [6], 133 (1925).—A mine containing large quantities of sillimanite has been discovered in India. Right to work it has been acquired by Henry A. Golwynne, a New York importer of chemicals. The deposit consists of enormous boulders on the surface. It is 100 miles from Calcutta, two or three miles from a railway. F. G. J.

Our imports and exports. ANON. *Pottery, Glass and Brass Salesman*, **31** [19], 9(1925).—Foreign trade figures on crockery and glassware given for and including the month of April, 1925. F. G. J.

Charles F. Binns—A man and a ceramist. R. C. PURDY. *The Pottery, Glass, and Brass Salesman*, **31** [19], 13(1925).—Address made at the annual commencement exercises of Alfred University on June 9th in eulogy of Prof. Binns, head of the University's school of ceramics for a quarter of a century. F. G. J.

The old Liverpool potteries. P. ENTWISTLE. *The Pottery Gazette and Glass Trade Review*, **50** [574], 604–8(1925).—This article is a report of a lecture given by E., Deputy-Curator of the Liverpool Museums, at a meeting of the Art Section of the Ceramic Society. The lecture was based on the results of seven years of research, during which time the town records were searched back as far as the year 1600, for the purpose of obtaining an authentic history of the old Liverpool potteries. P. D. H.

"Dust counting." ANON. *The Pottery Gazette and Glass Trade Review*, **50** [574], 598–600(1925).—This article is a report of a lecture given by E. L. Middleton, H. M. Medical Inspector of Factories at a meeting of the Ceramic Society and deals with the effect of dust on the human being, with special ref. to silica dust; the available methods of measuring the amount of dust in the atmosphere; and the precautionary measure adopted in order to combat the harmfulness of dust in the pottery industry. P. D. H.

A new ceramic material. ANON. *Ceramic Industry*, **4** [4], 294(1925).—In this mat. developed by the Germans and called "Keramonit," there is apparently a complete union of metals and minerals attained through heat. The body is prepd. by embodying a mesh or skeleton of whatever metal compn. desired in the ceramic mass, similar to the procedure followed in the manuf. of wire glass. In firing, the metal loses its identity and a homogeneous structure results. The mat. is absolutely immune to sudden temp. changes. It has very great mech. strength and is an excellent conductor of heat and a variable conductor of electricity. It is resistant to chem. action and possesses extreme flexibility permitting it to be bent at right angles. P. D. H.

Measuring metals' resistance to shock. R. G. WALTENBERG. *Chem. Met. Eng.*, **31,** 657–8(1924).—The results of notched bar impact tests are so dependent on the type, of specimen, that a method whereby a metal's resist. to rupture in impact may be expressed independent of the type of specimen used would be desirable. This author applies the method of Fillunger to monel metal. The energy to produce fracture in an impact specimen is considered as of two parts; that required to produce deformation, and that required to fracture the specimen. Formulas are given for detg. these energies, contg. two constants, δ and 2ω which are characteristic properties of the mat. representing its resist. to deformation and fracture. A formula for "notch toughness," e, is then derived, e equals δy plus 2ω where y is the eccentricity of the specimen, or the distance of the center of gravity of the area of fracture from the axis of the bore of the notch. By detg. notch toughness for several different values of y, values for δ and 2ω can be obtained, which are characteristic of the metal, and independent of the type of specimen making such tests on monel metal in a Charpy impact machine, the values δ equals 61 m. kg. per cv. cm. and 2ω equals 1.8 m. kg. per sq. cm. were obtained. A table of these values for other mat. is given. M. E. M.

Investigations in ceramics and road materials. H. FRECHETTE, L. P. COLLIN, H. GAUTHIER AND R. H. PICHER. *Canada Dept. of Mines*, **619**(1925).—The value of clay products made in Canada, in million dollars, is as follows: 1910, 7.6; 1911, 8.4; 1912, 10.6; 1913, 9.5; 1914, 6.9; 1915, 3.9; 1916, 4.1; 1917, 4.8; 1918, 4.6; 1919, 7.9; 1920, 10.7; 1921, 8.9; 1922, 11.4; 1923, 10.3. The 1922 peak, however, does not represent the quantity production of the 1912 peak. A notable feature since the outbreak of the war has been the marked rise and fall in the production of farm tile. From 1916 to 1919, when all other branches of the clay industry were at their lowest ebb, a rapid rise in farm tile production corresponded with the rise in the price of farm produce; during the ensuing 3 years, the demand for drain tile fell with the fall of farm produce prices. It will probably be some years before the building trades have become stabilized enough to bring brick production up to pre-war levels even in Eastern Canada. In W. Canada very little construction is going on. An exhibit of Canadian ceramic products, assembled for the British Empire Exposition at Wembley, embraced all the various types and color range of brick, structural and drain tile, sewer-pipe and other salt glazed ware, firebrick, stoneware, pottery, electrical porcelain, sanitary ware, enameled iron, and glass of various kinds. The use of the railroad tunnel kiln is advocated as the most efficient type of firing equipment; the fuel saving is 50–85%, labor costs are cut in half, ware is fired more uniformly, and time in kiln is reduced from 12 to 4 days. Work was continued on the investigation of road mats. adjacent to the main highways of the country, and a study was made of existing gravel roads in Ont. and Quebec for the purpose of establishing what properties of a gravel control its usefulness as a road mat., particularly with regard to the common fault of gravel roads known as corrugated, or "washboard," surface. H. H. S.

Chalk in chemical industry. W. A. ROTH. *Chemische Industrie*, **48**, 266–9(1925).—Follows $CaCO_3$ through its industrial uses in pottery, glass, iron and steel, sugar, and carbide manufacture. H. H. S.

The stream-line filter applied to the filtration of pigments. J. A. PICKARD. *J. Oil and Colour Chemists' Assoc.*, **8**, 36–46(1925).—The principle of the stream-line filter (*C. A.*, **18**, 2981) has now been adapted for handling suspensions contg. high amts. of solids which are to be recovered. Filtering packs have been developed for use in filter presses and suction filters, and these have quickly and completely recovered, in one filtration, $Fe(OH)_3$ and other ppts. which remained in suspension for weeks, and which readily passed unchanged through filter paper. It is particularly advantageous for filtering Prussian blue, and other troublesome pigments. Illus. (*C. A.*)

The industrial dust problem. II. Review of the methods for sampling aerial dust. L. GREENBURG. *U. S. Public Health Repts.*, **40**, 765–86(1925).—The important methods of dust sampling are reviewed and a list of 79 recent publications on the subject is given. An ideal method should reveal the no. of particles between 0.5 and 10 microns in size; of far less importance is the wt. of the dust because a single large particle does more harm than many smaller ones. The methods may be classified roughly as those involving condensation, filtration, washing, sedimentation, impinging, electrostatic action and resistance. Typical methods of each of these classes are described. (*C. A.*)

PATENT

Pyrometric cones with protective covering. H. SEGER and E. CRAMER. Ger. 406,835, July 1(1922); *Jour. Soc. Chem. Ind.*, **44B**, 319(1925).—More trustworthy temp. measurements are obtd., particularly in presence of moisture or of gases which are not inert, if the cones are coated with resistant resin varnishes, especially of artificial resins. H. H. S.

Bentonite in textile and paper manufacture. ANON. Brit. 226,850. *Chem. Trade Jour. and Chem. Eng.*, **76**, 559(1925).—A colloidal silicate, such as bentonite is

used alone or in conjunction with the usual finishing or loading materials such as agglutinant size, soap, starch, china clay or Epsom salts, for treating organic fibrous materials such as textile yarns, fibers and fabrics, and leather. In loading paper, the colloidal silicate is always used in conjunction with the filling material. The bentonite or other colloidal silicate is stated to have power of absorbing material and of being absorbed by the fabrics, etc. O. P. R. O.

BOOK REVIEWS

A Textbook of Glass Technology. By F. W. HODKIN AND A. COUSEN. 1st Ed. 551 pp. $5^{15}/_{16} \times 9^{11}/_{16}$ inches. D. Van Nostrand Co., New York, 1925. Price, $10.00.

Although the manufacture of glass is one of the oldest chemical industries, the literature is quite disconnected and this volume represents the first comprehensive attempt at a collection of the great mass of information, data and practical experience into a single authoritative treatise of such a nature as to permit of its employment as a general textbook on glass technology. It is, unquestionably, the best treatise on glass technology in the English language, and, so far as the reviewer is aware, is the only book thus far written which has covered the entire subject in so thorough and comprehensive a manner. The book is of particular value because it brings together in one place a complete but simple and concise discussion of practically every phase of the subject of glass.

This treatise is primarily intended to be used as a textbook but, owing to the adequate manner in which the field of glass technology is covered, can be used quite advantageously as a reference book. The authors, Messrs. Hodkin and Cousen, are experienced teachers, being connected with the Department of Glass Technology, University of Sheffield, and, as such, realized the great need of a textbook on glass technology of such a character as to allow the student to seriously attack this field in a systematic and thorough manner; thus, avoiding the necessity of having to wade through a maze of patent specifications, data, theories and more or less superfluous information in order to obtain more than a mere speaking acquaintance with this fascinating field. It should be emphasized here that the word "student" is used in its larger sense, namely, not only the students in universities and colleges, but any one who is trying to increase his or her knowledge and applies equally well to the plant manager, plant chemist or engineer and the ordinary workman. They can one and all materially benefit themselves by carefully perusing this interestingly written book.

Whether or not the reader can always agree with all of the authors' ideas, he should, at least, be grateful to them for a complete but concise discussion of both the old and the new in glass technology. In cases where doubt may arise and in all other appropriate cases, such as the referring to specific instances, the original references are cited, both sides being presented. Obviously, the authors have handled this situation correctly because what may appear to be an indisputable fact to some one may appear to be scarcely more than a guess to some one else, both of whom are authorities on the subject.

The first 61 pages, with the exception of the first 11, which are devoted to a brief historical discussion, are concerned with the wholly scientific side of glass, such as optical properties, viscosity, elasticity, density, thermal endurance, annealing, durability, etc. The next 71 pages are devoted to a discussion of the raw materials (basic oxides, acid oxides and miscellaneous materials) used in glass manufacture, their preparation, use and effects on the physical and chemical properties of the finished glass being mentioned. Also, numerous batch formulas are given which cover the entire field from selenium ruby glass to plate glass. Next, there is a 3-page discussion of decolorizing

glass followed by 14 pages devoted to the mathematics connected with calculations likely to be encountered in glass making. After this, the storage and mixing of batch materials are taken up, being followed by a chapter on the composition of glass and devitrification. This is followed by 91 pages devoted to heat and its various ramifications, such as combustion, fuels, thermochemistry and the valuation of fuels, pyrometry, etc. In this group is an excellent chapter on producer gas and gas producers in which various types of producers are clearly described and illustrated. Following this, is a 57-page discussion of refractories and their use, including silica brick, fire clays and the manufacture of glasshouse pots and blocks. Following this is a 77-page discussion of furnaces in which various types of annealing furnaces, oil-fired furnaces, direct and semi-direct furnaces and both recuperative and regenerative gas-fired furnaces are clearly described both as to construction and operation, being supplemented by drawings and photographs. The remainder of the book, 124 pages, is devoted to a discussion of the manipulation of glass in which bottle making, sheet glass, plate glass, rod and tubing, optical glass and hollow ware are interestingly treated. Various types of machines employed in these processes are described and illustrated both by drawings and photographs. Attention should be called at this point to the fact that the authors successfully avoided making their sections on furnaces, machines and processes simply a compilation of patent specifications and manufacturers' catalogues.

The book is singularly free from errors and inaccuracies. Since the writing of the book, discoveries have been made which will call for the revision of certain parts of the text if a second edition is published. For example, on page 169 appears the old Al_2O_3-SiO_2 diagram in which sillimanite is shown. It is now known that mullite, $3Al_2O_3$-$2SiO_2$, is the only compound of alumina and silica stable at high temperatures. Of course, this completely alters the diagram. This discrepancy also appears on pages 323 and 298. The wollastonite-silica diagram on page 173 is not complete.

The book is attractively bound and printed on good paper and has some excellent photographs. In all, there are 251 illustrations, including a photograph of the famous Portland Vase.

The book is to be highly commended for its simplified and complete presentation of a difficult subject. It is the reviewer's opinion that it should prove to be a valuable desk book for all whose interests touch on the technical side of glass.

A. ERNEST MACGEE

Non-Metallic Minerals, Occurrence—Preparation—Utilization. RAYMOND B. LADOO. McGraw-Hill Book Company, New York City. $6.00.

A book of 686 pages by Raymond B. Ladoo covering the technology of the non-metallic minerals.

The commercially important minerals are treated under the following heads: (*a*) composition; (*b*) general description; (*c*) physical properties; (*d*) occurrence; (*e*) production, consumption and reserve; (*f*) mining and preparation; (*g*) marketing; (*h*) specifications and tests; (*i*) utilization. Mining and preparation are in most instances more fully discussed than are the other phases.

The minerals are taken up alphabetically.

A valuable feature of the book is the bibliography which follows the discussion of each mineral.

In a short appendix appear sections on (*a*) scale of hardness; (*b*) scale of fusibility; (*c*) Seger cones; (*d*) atomic weights; (*e*) a short general bibliography covering books, periodicals and federal and state publications on non-metallics.

The book brings under one cover a mass of information of value to the ceramic technologist. The minerals which are of most interest to the ceramist are taken up in a very concise and in some cases a detailed manner. In a few instances, however, the

demands of the publishers for brevity have cut the discussion of some of the ceramic minerals unduly.

Any one desiring information in regard to sources, methods of winning and beneficiation, and utilization of the non-metallic minerals will find the book of value.

Due to his connection with the Bureau of Mines as Mineral Technologist, Mr. Ladoo was especially fortunate in having available all the resources of the government for collecting data both from the literature and in the field in the compilation of the data contained in this volume.

GEORGE A. BOLE

FALL MEETING

AMERICAN CERAMIC SOCIETY

Grand Central Palace
New York City

October 1, 1925

This is Ceramic Day at the Tenth Exposition of Chemical Industries.

The program for the day is sponsored by the Committee on Education of this SOCIETY.

General Theme — Shall ceramic products, their properties, specifications and service requirements be stressed more in collegiate ceramic courses?

Is it desirable and by what methods can instruction be given to men in the plants?

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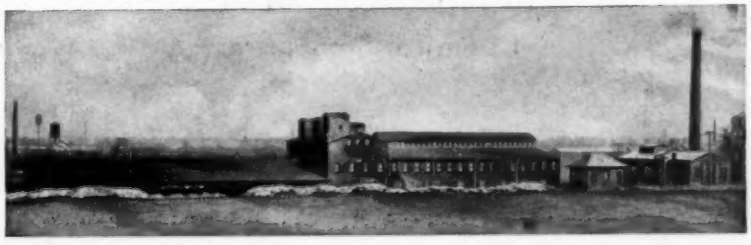

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BULLETIN

of the

American Ceramic Society

A Monthly Publication Devoted to Proceedings of the Society, Discussions of Plant Problems, Discussions of Technical, Scientific and Art Questions and Promotion of Coöperative Research

Edited by the Secretary of the Society Assisted by Officers of the Industrial Divisions

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EDITORIALS

WHAT THE SOCIETY IS AND WILL BE

The purposes of the Society are limited to promoting activities in support of researches and education in the science and technology of ceramic production. The Society operates through committees, meetings and publications. The seven Industrial Divisions of the Society are self-organized and motivated, each according to rules of its own formulation not in conflict with the general constitution and by-law provisions. Representatives from the Divisions make up the general committees, as also the Board of Trustees, thus making a democratic, "home rule" federation of all ceramic industrial groups, coördinated through a central office and board of control for the purpose of promoting research and education in ceramics generally.

The Society as now operating does not conduct laboratory investigations. The committees do search the literature for the purpose of compiling data, bibliographies and references. The Divisions and Local Sections hold meetings for the purpose of reading and discussing papers and committee reports. The Society publishes a *Journal* monthly in which is recorded the papers, discussions and committee activities. It also issues bibliographies and other collected information.

The Society is representative of all ceramic interests, the producer and user of ceramic products, the press, the schools, the research bureaus and

institutions. The financial, moral and intellectual support necessary to maintain such a central organization comes from those persons and corporations who believe in technical advancement through research and education.

The SOCIETY, as now constituted, cannot finance research nor conduct schools. It can continue to plan and advise on ways and means of making investigations, to collect and broadcast information. Trade associations, institutes by trade groups, the trade press, the universities, the art schools and clubs, the Federal bureaus, and the state surveys are essential factors to technical advancement in ceramics. These the SOCIETY encourages and coöperates with always. The ceramic departments in the Federal bureaus and some of the ceramic schools resulted directly from promotional activities initiated by this SOCIETY.

The SOCIETY coöperates with all organizations which deal with things relating to ceramic manufacturing.

Realizing the effectiveness of each group dealing with its own peculiar manufacturing problems, the SOCIETY proposed that manufacturers of like materials, through their respective trade organizations have a joint Research Institute. A scheme was presented and is being considered whereby these several institutes may collaborate and, on problems of common interests, join in support. The SOCIETY has even gone further in proposing that when all the industrial groups will have organized Research Institutes that they take over the SOCIETY and make it a joint means of promoting their several research and educational activities. Such would be the natural and the most economical outcome, for surely this SOCIETY will continue to be truly representative of all ceramic interests and there is no need of another central pooling agency in ceramic research and education. Form of organization, control and activity are readily amended to conform to the most productive service. Neither personal nor organization prejudices need be a factor. The AMERICAN CERAMIC SOCIETY will continue because it is of, by and for all ceramic interests, personal, corporate and institutional.

A GRADUATE FROM THE "SCHOOL OF HARD KNOCKS"[1]

Carrying last month's editorial a little further, not so very many months ago a learned professor made the statement: "I tear out the advertisements from all my magazines as soon as they come." It so happened that he was asked during the course of the conversation "where could such a particular article be obtained?" and his reply was he did not know. The

[1] Sent in by a member of the Society, himself a graduate of the school of "hard knocks."

article in question is one that is nationally advertised and if he had been a reader of the advertisements, he would know where to obtain the article.

Surprising as this may seem coming from a college professor, one whom you would expect to be a careful reader of advertisements, these cases are in the minority. Nevertheless, the advertisements not only in the *Journal* but all publications, carry a certain amount of information which, if properly analyzed, will serve as an education on the thousand and one things on the market.

Take for instance the Ingersoll-Rand Co. Recently they advertised their "service" and along with that they told of the many, many jobs their air drills and hammers were put on before they were placed on the market. After reading their advertisement we concluded there was considerably more to air drills and hammers than the average person had any idea of.

The Hercules Powder Co. have also carried on educational advertising telling of the way in which the ancients used to break stone, etc. It was of course, all bringing the reader up to the present day item they were manufacturing.

Now that the Educational Committee is starting on an educational campaign, those who are in the school of hard knocks, and those who were taken from school because of family necessities like Josiah Wedgwood, are eagerly watching for a pictorial description of the various things taught them.

Take, for instance, a pump recently shipped to the mountains of Central America. It arrived from the United States and the college engineer on the job was called away to another section needing his immediate attention. His departure left a student from the school of hard knocks in charge. The pump was needed badly but, being dismantled, could not be used. The company had previously met with such incidents and were prepared in this case—the result was a pictorial and plain English description of how to put the pump together. This did wonders for the manufacturer of these pumps and he is "cashing in" on it by selling to farmers who do not know any more about pumps than we do about what will happen next week.

Advertising in itself is an art, capable of being used to tell in words and pictures what is being done. Take away advertising and this would be a sorry place to live these days. To read and study the advertisements for only a minute, is like taking a short course in college—all the "dry rot" is removed and only the important items mentioned, enough so that, if you are interested, you can get all the technical details if you desire them.

PAPERS AND DISCUSSIONS

STUDY OF KILN LOSSES—AN EXAMPLE OF VALUE ACCRUED FROM COÖPERATIVE RESEARCH[1]

By George A. Bole[2]

About four years ago, Mr. Bleininger then with the Bureau of Standards, approached the heavy clay interests of the country through their respective associations in regard to research into the firing of heavy clay wares.

Mr. Bleininger was, I believe, working through the American Ceramic Society and the National Research Council.

Four of the associations approached took kindly to the idea and formed a Central Executive Committee, which committee instructed Mr. Bleininger as chairman, to select a Technical Committee, which he did. The research was planned by and carried out under the general supervision of this committee.

Less than a year after the field work of this investigation was completed, a group of refractory manufacturers approached the Bureau of Mines in regard to the possibility of carrying on investigations into the economy of firing refractory wares. Satisfactory arrangements were made through a committee of the Refractories Manufacturers Association.

The main differences in the two investigations were in method of financing and immediate purpose. The heavy clay investigation was financed by four heavy clay industries as a whole and the Federal Bureaus—Mines and Standards. The refractories investigation was financed by the plants visited in coöperation with the Bureau of Mines.

Field work of the heavy clay investigation was a general survey in a large field, the main purpose of which was to gather information. The refractories investigation has as its aim a demonstration of possible economies based on available information.

I wish to give you in a very sketchy way, some ideas in regard to coöperative research as carried out by the Government together with a few of the many interesting developments during the tests. My main purpose, however, will be to give you some idea in regard to what men in a position to know, think of these and similar researches.

My manuscript is therefore more than half either entire letters or excerpts from letters received in reply to inquiries sent out to the men who were in closest touch with the work.

It is as Mark Twain once remarked about a book that he was writing. He said that "it was both good and original. The part that is not original is good and the part that is not good is original."

In planning any researches in coöperation with industry, such as those in the firing of clay wares, there is always a well grounded difference of opinion as to how the work should be conducted.

We invariably have the group who believes that the only sure way to gather a lasting and increasing benefit is to solve the fundamentals once and for all. This group would carry out a research such as the heavy clay research under very accurately controllable conditions which would be capable of duplication from time to time, each phase of the work being attacked separately under conditions where one variable is studied at a time, all other factors being kept constant.

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[1] Presented before the Summer Meeting of the American Ceramic Society, Toronto, Canada, July 9, 1925.

[2] Superintendent, U. S. Bureau of Mines, Ceramic Experiment Station, Columbus, Ohio.

At the other extreme is a group of so-called practical men who hold that we really have a great mass of information that has never been put to work to the limit of possibilities. Why not use what we have so as to make it understandable to, and usable by the man on the plant?

Both concepts are of course correct. We do need more fundamental data. There are some phases of the problem of fuel economy which cannot go forward until we have such data, but it is just as true that the data cannot be put to work except it be made available to the man on the job through considerable tutelage and much demonstration.

Both schools of thought were fortunately represented on the committee which outlined the heavy clay investigation.

The committee in charge was convinced as a whole that we did not know enough about kiln operation to be able to outline a fundamental research intelligently, but should first survey the field, leaving to a later date the more detailed study of each separate kiln operation. In addition to the gathering of this very general information they felt that much practical good could be accomplished by applying the fundamentals that we already had to the fuel economy problem.

The plans as finally agreed upon were to have the water-smoking and the oxidation of clay wares studied in a fundamental way at two of the Government bureaus and to study quantitatively the heat necessary to fire clay wares at one of our universities. It is worthy of note that none of these problems are yet completed although much good work has been done on each of them.

The field work consisted of sending a crew of six men—three ceramic engineers and three fuel engineers with laboratory car to plants firing various types of heavy clay wares in various types of kilns using various fuels. In all, twelve plants were visited.

The types of kilns tested were—round and rectangular down draft; continuous chamber, car tunnel and semi-scove. The ware fired was common brick, face brick, hollow building tile and paving brick. Natural gas, producer gas, fuel oil and coal were the fuels used.

Most of the kilns tested were equipped with natural draft induced by either single or multiple stacks. Natural, forced and induced draft, with a combination of both forced and induced in one instance, were investigated.

The field work had, in general, three aims: (*a*) the collecting of engineering data in regard to kiln design; (*b*) a study of the heat distribution (heat balance); (*c*) the application of available information to the practical art of kiln firing. The third item consisted of a study of possible economies in fuel, kiln turnover and in the production of a superior product.

The results of the laboratory studies in water-smoking and oxidation which would have been very helpful were of course not available at the time the field work was being carried out. Laboratory control methods were gradually developed but were of little service, so far as a more efficient field work was concerned, until near the end of the investigation.

It was not to be expected that a crew of young college graduates, even under competent supervision, with little back of them beside theory could get in a single demonstration the ultimate efficiency out of a given kiln. They did, however, demonstrate the *methods* whereby large savings could be and were later realized not only on the plants visited but at many plants where similar work has been done with this work as a basis and inspiration.

It was thought before the tests started that, as the investigation progressed, the crew would be able to make a much better job of it. With the exception of the heat balance work where technique is so large a factor, this did not appear to be the case, due to the fact that each succeeding test was so different from the preceeding type of kiln, raw material, ware fired and fuel used.

The task of correlating, tabulating and analyzing such a heterogeneous mass of data as that gathered during such an investigation was a monumental one and the conclusions drawn are at best only tentative.

Those unfamiliar with research who expected a recipe for firing all types of clay ware with all kinds of fuel in all types of kilns to result from the investigation were disappointed with the work. Those who realized from the beginning that such a research could be expected to form only the basis for further work, both fundamental and practical, were pleased.

All comments which have come to our ears have lined up somewhere between these two extremes.

A later investigation was undertaken in coöperation with a group of refractory manufacturers in which seven plants were visited. It was similar in general outline to the heavy clay investigation, but included only one type of ware—refractories—all fired in round down-draft kilns with the same type of fuel—coal. It proved to be a very much more satisfactory undertaking. Of course we must not overlook the fact that we had the experience and technique of the heavy clay work behind us as an invaluable aid both in planning and carrying out the investigation. This should be considered as one of the advantages accruing from the heavy clay research. However, discounting this fact, it was very apparent that reducing the variables enabled us to gather momentum as the work progressed and to compile our results in a more simple manner and in general to render a more direct aid to the coöperating parties.

During both investigations the same kiln at each plant was fired twice. The first time by the plant crew with the Bureau crew observing and collecting data. The second test was directed by the Bureau crew. It is most interesting to note that in every plant visited, with two exceptions, the kilns were fired off during the first test in a much shorter time than was plant practice and in many cases with a considerable saving in fuel—all of which goes to demonstrate that the average kiln foreman can do a better job than he ordinarily does when he feels that his reputation is at stake.

The most immediate benefit which accrued from these researches, but in the long run a minor one, was the actual saving in time and fuel which the crew demonstrated could be accomplished at the various plants visited. This saving varied from 0% to 50% in fuel and in time from an increase of 5% in one case to a saving of 45% in another. Kiln waste was reduced markedly at several plants. A demonstration of the methods through which savings could be expected was of far greater importance than the savings themselves, large as they were, as it is through this means only that the industry at large is benefited.

It would require a much longer time than is allotted me to either describe the work or to point out in an adequate way, what was accomplished at each point. You may be interested, however, to hear of a few isolated instances.

It was found in many cases that the efficiency of a kiln was greatly reduced by setting the ware improperly. In one instance a slightly more open setting with a false flue system over the floor cut the firing time in half—reduced the fuel consumption 40% and raised the marketable ware from a plant average of 80% to one of 95%. This and other similar examples stress the fact that the setting is in reality a vast system of flues which serves to distribute the heat properly and at the same time interferes as little as possible with the normal functioning of the kiln.

The fuel engineers were inclined to scoff at the ceramic engineers when they saw their first dead bottom fire box. Even when on somewhat more familiar ground, they were shocked when they saw their first 30-inch fuel bed on a horizontal grate. However, before the tests had proceeded far they were free to admit that many of the principles of efficient heat production in boiler furnaces are inoperative in the case of a ceramic

kiln. The fact became more and more evident as the tests progressed that efficient kiln firing is made up of two factors, namely, efficient *production* and efficient *utilization* of heat and, of the two named, the last is by far the more important.

The all important factor of the proper distribution of heat in a kiln was studied by thermocouples, blind cones and static pressures in the heating chamber and by porosity, shrinkage and specific gravity of the ware after it was removed from the kiln. Draw trials were resorted to in a few cases. As all these means of control are well understood by the ceramic engineer with the possible exception of static pressure, I do not need to comment further than to say that they all have an important place in the control of kiln losses.

A draft survey in several of the kilns demonstrated the fact that the heat distribution was especially good and kiln losses small when a positive pressure is maintained as far down in the kiln as possible and still maintain satisfactory operating conditions. A study of drafts at several points within a kiln often shows the cause of improper heat distribution where temperature measurements indicate only that such a condition exists. At one plant draft curves indicated the cause of a cold cone in the crown of the kiln to be due to a minus pressure well up in the center of the setting. The setting was later corrected and the cold cone disappeared.

At one plant where a difference of five to seven cones in kiln temperature was plant practice it was found possible to reduce this difference to less than three cones by firing one end of the kiln (New Castle type) very close (really a gas producer) and allowing the fires in the other end to burn down in order to admit sufficient air to burn the fuel gases within the setting. A change in the setting so as to produce a vertical rather than a horizontal flue system helped accomplish the desired results.

Kiln losses were reduced in two cases by employing induced draft. The normal losses were due to the settling of moisture in the bottom of the kiln with subsequent kiln marking and cracking of the ware. This condition was remedied by the more rapid elimination of the moisture as the water-smoking progressed.

Losses due to the flow of heat through kiln walls, heat stored in the kiln structure and in the ware, losses in flue gases, combustible in ash, etc., were studied and constituted the basis for figuring the heat balance. This work was the most important phase of the investigation so far as kiln design is concerned although the data in regard to kiln proportions can be of great value to the kiln designer as well as to the plant management.

There are other advantages which have accrued to the industry from these and similar tests in addition to the few examples already pointed out and many others of a similar nature which could be enumerated if time permitted. The advantages to which I refer are of a less exact type but are larger in their scope than are the more tangible ones. In writing to a number of the men most closely connected with these researches in the capacity of plant operators, technical advisers, and association secretaries, I find that the one point most commonly stressed is that these tests have demonstrated in a very specific way that savings can be made by the application of scientific principles to plant practice and that with such tests as an inspiration many plant superintendents have caught the investigative spirit and are producing results.

The most frequently expressed constructive criticism of the work, especially that on heavy clays, is that it stopped short of accomplishment in that it did not "get across" to the firemen. We candidly acknowledge that this is true and it should be the next step in a well-defined program.

The four association secretaries have expressed this same idea in very interesting communications which I shall read:

"I am afraid my views are rather well known on that subject (advantages accruing

from kiln investigation), and I am afraid that they are not very extensively agreed to by other members as to their results.

"I thought then, and still feel, that so far nothing has been accomplished to boast overly much about. A good start was made and no more. The Joint Research Committee instead of branching out into a highly theoretical field of doubtful value to the industry, even if its aims were accomplished, should have continued in existence under its own arrangement and should have devoted itself to devising methods of making practically available to the plants day by day, results that the research program indicated could be had if properly followed up. The Joint Research Committee and various bureaus of the Government, who may see fit to interest themselves in the matter, can do more service by considering the application of research data already gained than by the further accumulation of data.

"All the propositions I have heard so far discussed in regard to further research, I must confess, are so vague in their terms and purposes as to be obscured to technical men in the industry as well as the leading operators. My idea of further activity in connection with clay products research is to come down to earth out of the clouds and be practical rather than theoretical. I appreciate the fact that this is stated in the form of a negative view and therefore may not be constructively helpful. Nevertheless, there is a remedy when sufficient people are interested in the matter to apply the remedy."

Another communication states:

"There is no question but that our industry has benefited to a great extent by the publication of the research work undertaken by the Bureau of Mines in coöperation with the four heavy clay products industries.

"It is rather difficult, however, to get any definite statements as to results although one of our manufacturers did state that on a single plant he made a saving of $20,000 the first year. This probably has been duplicated to a greater or less extent in a number of other plants.

"One difficulty in all research work lies in the interpretation of these results to the small manufacturer who has not had a technical training. Undoubtedly, a great deal of the value is lost on this account but we contemplate an attempt to rectify this condition in the near future.

"I further believe that for the good of the clay products industry, this burning investigation should be continued and carried to a conclusion."

Another reply stated:

"The investigation of the Bureau of Mines was timed during a period of unprecedented research in burning facilities and methods. Without doubt, your work has vastly stimulated confidence in the fact that burning costs can be materially reduced. I believe that most of our members have carefully studied the burning report, and although we would not necessarily know about many cases, I am quite sure that the interests have been general and that the principal good has come from the stimulation of thought and study to apply your findings to different sets of conditions."

The other secretary reported:

"Roughly I would say that the results are just about in the same proportion as those resulting from the activities of this office. A minority of the membership will grasp and use any valuable information. Unfortunately the majority does not seem to know how to apply it. I think you can safely report, however, that out of our membership many of them have been able to apply the information resulting from your investigation and have made notable saving in expense on their burning process."

It will be interesting for you to hear the variety of opinions as to the value of these researches as expressed by plant operators. The five following letters are from plant

superintendents where plant practice was so good that little improvement was possible. You will note a just and excusable pride in the fact that their operation could be little improved by the Bureau crew.

(1) "We were much interested in the work of the committee at the time, but cannot honestly say that we actually received any benefits as the result of this work. We maintain a force of ceramic engineers of our own, and are constantly following the matter of burning of our kilns in our various plants, and therefore have collected considerable more data on this subject than would be possible on any one trip of the kind referred to."

(2) "You will remember that tests run by the crew at our plant showed no fuel saving to speak of and even a slight decrease in percentage of No. 1 ware, but it did at least prove that our methods then in use were fairly efficient and sound. It also gave us such information as the amounts of excess air carried at various stages of burning, the pounds of coal burned per square foot of grate area per fire at various stages of burn, and other similar data which has helped us considerably since that time, and which would have been very difficult for us to obtain otherwise."

(3) "We have improved our burning practice considerably since the crew was here. We have raised our finishing temperature about 2 or 3 cones and are burning our kilns much more uniformly from top to bottom than we were at that time. Our coal consumption has been increased slightly but not unduly, considering the better results we have obtained.

"How much of this improvement has been due to the work done by the crew here is hard to determine. We have applied some of the changes in practice recommended in your report and have gone just the opposite way on other recommendations. On the whole, the direct effect of the work done here has been rather small but the indirect effect has been very beneficial and has been well worth the money and time invested. By indirect effect I mean the effect of the crew's investigations upon our own men who handle the kilns. They have shown a spirit of coöperation in effecting changes in methods and a willingness to try out new ideas, which have been very gratifying.

"They now believe that there is something in the technical control of burning which will get results which cannot be obtained by rule of thumb methods and this belief of theirs has made our burning problems much simpler of solution than they were formerly.

"All of this has taken time to work out and I believe that we will derive further indirect benefits from your work as time goes on. I hope that this report will answer your purpose."

(4) "The only real result that I see from the work which your department did while at our plant was the fact that you furnished us with scientific and technical data as the result of the experiment. It must be acknowledged that you could not show a fuel saving nor a better product. We pat ourselves on the back in this respect and do not criticize the Bureau.

"The subsequent work done, however, at other plants, according to the reports which I have read, show that the work accomplished was wonderful saving of fuel, instructions to burners as to how best to control their kiln temperatures and fires, the best type of setting to use to obtain results and any number of other things that were brought out which have probably saved the industry a considerable amount of time and money.

"On a whole I would say that the work was more than successful and the cost involved was merely a 'drop in the bucket' with the savings which should result from such a series of tests."

(5) "The plant visited by the crew was greatly benefited by the data gathered. While very little time and fuel were saved, the methods developed by your crew un-

doubtedly improved the product and most important of all, increased the length of life of the kiln lining and bottoms.

"A number of the other plants visited by your crew have advised me that they were benefited not only as to improvement of product but were able to save both time and fuel."

Plants where large savings were made write through their superintendents as follows:

(*a*) "Since the publication (Burning Problems of Industrial Kilns) has reached our hands, we have made very great use of it. We have been able to shorten the time of burning somewhat and also decrease the amount of coal per thousand brick. The greatest advantage I find is attaining the scientific data with regard to our particular kilns. We were very much in need of these facts that the Bureau has given us.

"I sincerely hope that the Bureau of Mines may see fit to continue these inspections to other plants, for I know the good derived would certainly repay the effort."

(*b*) "We wish to say that the investigation called to the attention of our formen and also the workmen the importance of watching closely the details of burning.

"Also the importance of getting proper draft and having the kilns kept up in good order. It was important to the management in calling attention to the fact that a higher grade coal would produce better results.

"We are glad to have your coöperation in helping solve some of our burning problems, and we have no regret for the time, interest and money which was expended in conducting this test."

(*c*) "We would say that since investigation of our kilns by your crew, we have not experienced trouble with our standard brick in cracking from too rapid drying. Our actual coal consumption is considerably reduced as compared with amounts consumed in prior years, allowances being made for difference in cost of fuel and difference in rate of production.

"We feel that the money spent for this service has proven most profitable to us."

(*d*) "We were well pleased with the results obtained at our plant. We had felt that burning the ware was one of the processes of manufacture that we knew little about. We didn't know how our losses were distributed nor did we have any idea of the composition of the products of combustion. We did not have the instruments nor the equipment to measure these things.

"The work which you did taught us many things and also enabled us to study and think of these problems more intelligently ever since.

"Your suggestion that during a portion of the burn, one end of the kiln be fired as a producer and the other end supply the excess oxygen to burn this gas at the center of the setting, was a novel idea and a very good one and was practiced by us, with the result that we were able to increase the temperature considerably at the center of the setting.

"Altogether, we considered the work well worth while, and we are glad that we did it."

(*e*) "The work carried out by your department, I would say, was very important and of a practical nature. As a result of the data accumulated on our plant covering our burns, we have been able to effect some quite substantial savings in burning. In addition to this, I would say, that it attracted a great deal of attention from our men and had the effect of 'pepping them up' and caused them to do more thinking about their work. Such results are always helpful."

Interesting letters from two of the members of the Technical Committee in charge of the heavy clay investigation in which they express ideas both as to results accomplished and future work needed, follow:

"Answering your inquiry concerning the work which has been done on the subject of kiln firing, permit me to say that in my opinion it was well worth doing because of its educational value. It has aroused the attention of the manufacturers to the importance of doing systematic firing and saving both time and fuel by following the principles laid down in the report. It is very difficult to do strictly original work along these lines because much of it has been done before. But the present work was done in a more complete way than any other effort. It therefore represents a more unified investigation.

"I still believe that there is vital need of a fundamental study of heat transfer such as I tried to have incorporated in the research under discussion. This would deal with the velocity of the gases of combustion and the rate at which they transfer heat to the charge. It would also deal with the conditions of pressure within the kiln, that is, whether there is greater uniformity of temperature with minus than with plus pressure. I am sure that some day this will be done. The most outstanding feature of the work done is that of Dr. Washburn on the heat consumed in the firing of clay."

". . . .benefits accrued from this investigation were (1) more general knowledge of what happens at each stage of firing; (2) more general ability to use control devices; (3) economy in kiln management and (4) a fair idea of how the heat was used or wasted.

"Until more of the specific or fundamental data are had on heat reactions, absorption, and recovery in fuel, ware and kiln structure, exact determinations of the factors affecting economies cannot be determined.

"Until there are kilns available in which design and construction alterations can be made there is not going to be the largest return from the kiln study.

"A thorough demonstration of the use and value of control apparati, and a training of kiln firemen generally in their use would be a distinct step over the present general practice. The savings resulting from intelligent use of pyrometers have too often been demonstrated to warrant any one attempting kiln economies without their aid. Firemen generally should be trained in the use of draft gages; fuel and ash weighing and analyzing.

"In a word the greatest value ultimately from these kiln studies will be better kilns and better posted firemen."

INDUSTRIAL RESEARCH[1]

By E. Ward Tillotson[2]

The University of Toronto and the industries of Canada are to be congratulated upon the establishment of a course in ceramic technology in that great institution of learning. The ceramic industries are so basic in their relation to other industries and so essential in supplying needs of modern life that they are deserving of the best that science affords.

It is the purpose of the University to direct the advancement of science and to furnish men trained to serve the industries. It is the privilege of industry to take advantage of these products of the university for its greatest advancement.

The trained mind is an essential factor in modern industry. It may find its place in work of organization or management in which case special training in engineering and economics are required, or it may function along the line of research or scientific investi-

[1] Read at the Summer Meeting, American Ceramic Society, Toronto, Canada, July 9, 1925.

[2] Assistant Director, Mellon Institute of Industrial Research, Univ. of Pittsburgh, Pittsburgh, Pa.

gation of processes and products, which necessitates specialized training in one or more of the experimental sciences. Progressive industry is constantly pushing its outposts forward into new territory, broadening its field, improving its positions and, in addition, accumulating a reserve of knowledge in preparation for future development.

Science, the classified store of accurately observed facts, is dependent upon the powerfully effective instrument, research, to gain new knowledge. Industrial research translates this knowledge into practice, seeks new data which will be of practical value, and endeavors to utilize the facts and the methods of science for the greatest benefit of industry.

Technically trained men, engineers, chemists, ceramists, metallurgists, physicists and biologists, all products of the university, are important in industry because they have available or can procure and then classify and apply information of practical value. Science and research now have recognition and support in the United States because they are paying heavy dividends to American industry—one half-billion dollars annually according to conservative estimates. Their industrial future is rich in promise because they are constantly broadening their scope, their methods are growing steadily more effective and the means of reducing their accomplishments to practice are becoming more satisfactory. Industry must indeed look to institutions of higher education for men and means to insure its reserve of technical knowledge, to satisfy the requirements of the present technology and to prepare for the developments of the future. It is important, however, for the most effective industrial research that the university should not merely produce trained minds nor that industry should only utilize the services of technical men. The united efforts of both parties are necessary to accomplish the desired results, which require an appreciation on the part of the university of the needs of industry and an understanding on the part of industry of what the university is able to furnish. Thus industrial research serves as a connecting link, a strong and useful bond between science and education on the one hand and practice and industry on the other.

Certain lines of industrial research, to be sure, may well be carried out in the laboratories of individual companies and of associations, but that does not lessen the worth of what the institution of learning may contribute.

In the United States industrial, chemical and ceramic research is being conducted in laboratories of universities and in experiment stations connected therewith, in the laboratories of Government bureaus, in privately owned commercial laboratories, and in the research laboratories of corporations and of trade associations. The number of such investigations is constantly growing.

Mellon Institute of Industrial Research of the University of Pittsburgh represents the development in connection with a university of an extensive organization, the primary object of which is to conduct industrial, chemical and ceramic researches. At the present time 55 separate investigations are under way, requiring the services of about 100 highly trained investigators.

Of these 57 industrial fellowships, 11 are within the field of ceramics. One deals with general refractories, two with enamels, three with sewer pipe, two with glass-house refractories, one with special metallurgical refractories, one with flooring and wall tile and one with the manufacture of glass mirrors.

At present Mellon Institute is receiving from industrialists approximately $500,000 annually for the support of this work of which approximately $70,000 is devoted to ceramic investigations. The continued and healthy growth of Mellon Institute since the inception of its work in 1907 indicates, it is believed, a real and growing realization on the part of industry of the practical value of science and of research.

PITTSBURGH, PA.

CERAMIC ENGINEERING CORRESPONDENCE COURSES AT NORTH CAROLINA STATE COLLEGE[1]

By A. F. Greaves-Walker

Fifteen years ago one of the high grade institutes offering engineering courses by correspondence took up with me the question of the feasibility of giving ceramic engineering courses by correspondence. I could see no reason at that time why such courses could not be given, and after our experience of the past six months I am surprised that so fertile a field should have been left untouched. A study of the catalogs and bulletins issued by the correspondence schools and large universities offering courses by correspondence revealed the fact that practically every course of study that could be taken by resident students in the educational institutions of this country was offered except ceramic courses.

There can be no doubt that the technically trained ceramist has made a tremendous impression on both operators and workmen engaged in the various branches of the industry, during the past ten or fifteen years. This impression has been deep enough to create a desire, in hundreds of practical men who cannot attend college, for an opportunity to obtain some technical training. Heretofore the short courses offered the only opportunity for these men and they, naturally, could only reach a limited number.

While I had had no experience, either as an instructor or student in correspondence work, I could not see any reason why courses in ceramic engineering subjects could not be given as easily and successfully as physical chemistry, geology, heat engines, soils or mechanical drawing. I felt that if a practical man could read and understand an article in a trade magazine on such subjects as kilns or firing, he could understand, especially with some assistance, a text book or lecture.

All the correspondence courses offered by North Carolina State College carry college credit, this credit being based on from twelve to sixteen assignments or lessons equaling a three-credit course for one term in residence. This matter of college credit naturally carries with it the question of correspondence students meeting the college entrance requirements. It was my opinion, however, that few men in the ceramic industries, under the age of twenty-one years, would apply for these courses and this would allow us to admit them on the same basis as special students. As is the rule in other colleges, the question of admission of these students is based on consideration of the individual case. Each case is judged from a transcript of the student's school record submitted with his application for admission. So far about one-half of the sixty-two students entered have had only a common school education.

As we have been especially anxious to encourage men holding foremen's and clerks' positions we have tried to impress upon those interested that it is not necessary to take a final examination if college credit is not desired. In such cases when a man finishes his last assignment he has finished the course but is marked "incomplete" as is a resident student who fails to take his final examination. When a final examination is desired a high school principal or someone connected with an educational institution near the student's home is appointed an overseer. I might add here, that so far we have not refused to admit a single student, no matter how poor his preparation, and we have had no students who have requested a final examination for college credit.

We limit students to not more than two courses and advise taking only one at a time. Experience has shown that very few students can successfully handle more than two correspondence courses at a time.

In working up the first courses we decided to use available text books and as nearly

[1] Presented at the Summer Meeting, American Ceramic Society, Toronto, Canada, July 9, 1925.

as possible made each assignment cover one chapter. This could be done because the student is not limited as to time. There being very few text books, however, the courses worked up later were in the form of lectures.

When a text is used, a lesson aid of explanation of the text accompanies each assignment.

As nearly as possible the work parallels that given the resident students taking the same course. Under the circumstances it is necessary to simplify it as much as possible and to go into more detailed explanation. It is borne in mind, however, that practically all of the students have a plant background and that the plant is their laboratory.

Each assignment contains from five to twelve questions, usually ten, and the answers to these are returned to the instructor. It is assumed that the student will study the lesson and answer the questions without reference to the text or lecture, but it is readily noted that most of them practically copy the answers where possible. Personally I can see no great objection to this as I feel we have accomplished our purpose if we only succeed in getting the student to read through the text book or set of lectures. We are not, as in the case of resident students, interested in their keeping up to a certain standard in order to obtain a degree, because we do not require them to take a final.

It is rather remarkable that out of several hundred assignments that have been returned to me only three have failed to receive the passing grade of 60. Two of these were the work of a brick plant superintendent who had had only four grades of grammar school. The company paid this student's fee and he was the first one to complete a course. His average grade for the course was above 80.

Very few students have experienced difficulty with their lessons and only in cases where formulas were used. This was anticipated and when problems are given, straight arithmetic is used whenever possible.

We eliminate prerequisites almost entirely by devoting several of the first assignments to a general review or resumé of the preparatory courses which would be taken by resident students. In other words we have studied the type of students likely to be interested and adapted our courses to his needs.

The amount of work required of the department and the cost has exceeded our expectations. We have kept a fairly close check on the costs and find that a course of fifteen assignments costs approximately $330.00. This includes the instructor's time in writing up the course, the stenographer, stencils, postage and the overhead of the Extension Division.

As a standard fee of $2.50 per credit had already been set for all correspondence courses at North Carolina State College and our courses run from one to three credits, the maximum charge is $7.50 per course. This covers the total expense of the student except the cost of a text book if required and the postage when returning assignments to the college. We estimate our present fees will never cover more than 50% of the cost per course. Our attitude, however, is that we are making a contribution to the ceramic industries.

We have been offering courses for six months and have registered sixty-two students. In view of the known demand for such courses, this is, in our opinion, a poor showing. We attribute this, first, to our inability to reach the men who are interested in such courses with the information that they are available; second, to the impression that the courses are limited to citizens of North Carolina, and third to the fear on the part of many that their preparatory training will not permit them to do the work. The distribution of our students is very wide, nearly every state in the Union being represented, with foreign students in Peru, Australia and Canada.

We have had no opportunity to judge the mortality of our correspondence students. It is a well known fact that mortality among correspondence students is high. We have no reason to believe that we will not strike the average.

Most of the time since starting this work has been devoted to writing courses. With more assistance next year we hope to be able to devote more time to interesting employers in organizing groups who will study these courses at night under supervision. Many more men could be reached through such an arrangement and especially those who are not capable of handling a course alone.

So far we have devoted ourselves to courses of particular interest to men in the heavy clay products industries. We have had as many requests for courses from men in the enamel, glass, pottery and abrasive industries as from the heavy clay. We feel these men should be taken care of and unless some of the other departments undertake the work it is our intention to cover the entire field as rapidly as possible. There seems to be little reason for duplication of effort in this field but there is no reason why each department could not devote its efforts to a particular branch of the industry. We are now covering heavy clay and refractories; there still remains enamels, whiteware, decorated pottery, glass, cements and abrasives.

SCHOOL OF ENGINEERING

NORTH CAROLINA STATE COLLEGE OF AGRICULTURE AND ENGINEERING, COLLEGE EXTENSION DIVISION CORRESPONDENCE COURSES

(Ceramic Engineering) (Course 208B)

Kilns and Burning. Assignment I

Required Text.—"Burning Clay Wares" by Ellis Lovejoy, published by T. A. Randall and Co., Indianapolis, Ind., price $7.50.

Assignment.—Chapter I to bottom of second paragraph on page 15—"Clays and Their Mineral Contents."

Supplementary Discussion. Method of Study

This course is a study of the general principles underlying the burning or firing of clay products and the kilns in which the burning process is carried on.

Clay is a mixture of particles of minerals and rock of variable sizes and kinds, or a mixture of crystalloids and colloids. The characteristic properties are first, plasticity when wet and second, durability when burned. Clay is not of constant chemical composition nor of constant mineral composition. Its variability in its composition and physical properties is due to the mode of origin and the material from which it is formed.

The burning of clays brings about certain chemical and physical changes and the student beginning the study of burning or firing should have studied the elements of physics and chemistry or should be familiar with the changes which take place through practical experience.

For acquiring a knowledge of many subjects, such as history, languages, etc., the average student is likely to rely mainly on memory. When the student has committed to memory the statements of the author he feels his part has been performed. In the study of burning or firing the "whys and wherefores" should be considered; in other words, the student, in order to master the subject, must reason things out as he proceeds and should compare the statements in the text with his own observation.

The variability in the composition of clays makes almost every operation an individual problem. For this reason the student may find statements in the text with which his own experience does not agree. It must be remembered, however, that the same basic principles govern in all cases.

In the study of any subject one must be able to see the facts and principles with his mind's eye; that is, visualize them and know them to be true irrespective of any

statement in the text. The understanding of the application of the principles also aid in the appreciation of their significance.

The student taking this course who has not studied physics or chemistry will encounter difficulties where physical and chemical terms are used in the test and will have difficulty in understanding references to physical and chemical reactions. In such cases he can invariably get a simplified explanation from some of his associates, or even from his employer. Such students should not become discouraged over the first few assignments as they are in any case obtaining a great deal of real and helpful knowledge by following the course to its finish, even though their grades on the questions may be unsatisfactory to them.

Read the statements concerning the subject under discussion; read the name of the subject always. Try to interpret the meaning of the subject before attempting to answer the question. If you do not understand the subject, state your difficulty to your instructor. Your instructor can obtain very much better information of your real needs in the course if you are free in stating your difficulties on the recitation sheet.

Remember that the lesson sheets make only the absolute requirements, not the total possible requirements. You will not be injured by doing more than the actual letter requirements of the lesson sheet.

Plan of the Lesson Sheet

A. Assignment.—Read the lesson sheet and text carefully before attempting to solve the questions.

B. Lesson Sheet Suggestions.—General statement and questions are placed on the lesson sheet. These are intended to assist the student in the interpretation of the subject matter and principle involved. Give careful attention to these. The failure of the student to give attention to this part of the lesson sheet will appear on the later recitation sheets sent in to the instructor.

C. Recitation.—All questions or problems on lesson sheets are to be solved and sent to the instructor. It is from this work that the instructor judges the degree of mastery of the subject which the student is attaining.

Be careful to put your recitation work in such good form that you can interpret it easily and show the same courtesy to your instructor. Always leave with each exercise enough space for the comment of your instructor. This is where your personality and his come closest together.

D. Summary.—With each recitation send in a summary of the lesson, telling in your own words what it is about.

E. Personal Problems.—With each lesson make a brief statement of the difficulties which you meet in preparation of the lesson. This enables the instructor to suggest fittingly for your personal advantage.

Lesson Aids

In order to have a good foundation for the study of the subject of "Kilns and Burning" the student should have a knowledge of the raw material which is to be burned. As most of the students taking the course will be engaged in the clay industry and have at least some knowledge of clays, it will be assumed that a short review of the subject as given in the first chapter of the text will suffice.

One of the things that always makes the burning of clay products a problem is that each clay encountered is a mixture of minerals differing to some extent from every other clay, in fact to make the problem more difficult, each deposit of clay usually presents a varying mineralogical composition within limited areas.

The student should get a thorough understanding of the author's explanation of a flux, a eutectic and a eutectic mixture. It should be noted that the silica and alumina in clays must be considered as fluxes just as are lime, iron and the alkalis.

It is important to remember, too, that the fineness of grain has a very important bearing on the burning characteristics of a clay. Any student who has examined a piece of broken vitrified clayware will have noted that the larger grains of clay often remain practically intact while the fine grains have lost their identity. How much more heat would it have taken to produce a dense body had all of the grains been of the same size as those larger ones?

A curve showing the eutectic points of a mixture of pure lime and pure clay is attached. An average clay or shale may have four or five eutectics, one for the potash and silica, one for the iron and silica, another for the potash, iron and silica and so on for every possible combination, each one occurring at a different temperature. The student who has observed the burning of clay products will get an idea from this as to one of the reasons for kiln marking, which often takes place at temperatures far below the point where the ware is finished.

That clays become viscous in the kiln is shown by the fact that they become misshapen. Viscosity is the "relative resistance of a liquid or solid to force tending to change its form." Example—kerosene is less viscous than black oil, or kerosene has a *low* viscosity (it is thin), and black oil has a *high* viscosity (it is thick).

When a clay reaches a point where some of its ingredients begin to fuse it begins to get less viscous and as the temperature increases the viscosity decreases. If the temperature is carried high enough the viscosity will become so low that the ware will "squat" or slump and eventually melt to a slag.

Questions

1. Is a clay a mineral?
2. What is the common base of all clays?
3. What bases or impurities are always associated with kaolinite in common clays and shale?
4. How are clays converted into shales?
5. What is a flux?
6. What fluxes do we find in clays?
7. What is the minimum fusion point of a mixture of minerals called?
8. Discuss briefly the effect of fineness of grain on burning.
9. Why are heavy clay products, except a few special wares, not burned to complete vitrification or to the point where they show no absorption?
10. Give a definition for viscosity.

Physical Geology. Assignment I

(Geology) (Course 120A)

Required Text.—"Introduction to Physical Geology," by W. J. Miller, published by D. Van Nostrand, New York City, price $3.00.

Assignment.—Chapter III of the text—"Materials of the Earth—Rocks."

Supplementary Discussion. Method of Study

The student will be at some disadvantage in not being able to take some laboratory work, but as the whole outdoors is a geological laboratory he should not fail to observe the various geological phenomena whenever the opportunity offers. Every stream bed, railroad or highway cut, every hill and mountain, lake and seashore has its story to tell.

Every rock outcrop does likewise. In addition to keeping his eyes open and observing geological features when going from place to place the student should take advantage of any opportunity to visit geological museums or laboratories in order to examine collections of rocks and minerals, maps and models. In addition to its general educational value a knowledge of geology is an invaluable asset to anyone who uses natural raw materials.

The student should read the first paragraph under Chapter I and get a clear idea of the definition of geology and its subdivisions.

Although a number of geological facts such as the divisions of geological time and the names of rocks and minerals must be memorized the student must not feel that when he has committed to memory the statements in the text he has fulfilled his part, as in order to master the subject he must reason things out if he is to be able to identify the various minerals, rocks, and formations and their mode of origin. He should constantly compare the statements in the text with his own observations.

Read the statements concerning the subject under discussion; read the name of the subject always. Try to interpret the meaning of the subject before attempting to answer the questions. If the student does not understand the subject, he should state his difficulty to his instructor. The instructor can obtain very much better information of the student's real needs in the course if he is free in stating his difficulties on the recitation sheet.

Remember that the lesson sheets make only the absolute requirements, not the total possible requirements. The student will not be injured by doing more than the actual letter requirements of the lesson sheet.

Plan of Lesson Sheet

A. Assignment.—Read the lesson sheet and text carefully before attempting to answer the questions.

B. Lesson Sheet Suggestions.—General statement and questions are placed on the lesson sheet. These are intended to assist the student in the interpretation of the subject matter and to explain it more fully where necessary. Give careful attention to these. The failure of the student to give attention to this part of the lesson sheet will appear on the later recitation sheets sent in to the instructor.

C. Recitation.—All questions or problems on lesson sheets are to be solved and sent to the instructor. It is from this work that the instructor judges the degree of mastery of the subject which the student is attaining.

Be careful to put your recitation work in such good form that you can interpret it easily and show the same courtesy to your instructor. The instructor cannot take for granted that you understand the question unless you answer it fully. Where a discussion is asked for always cover the subject in such a manner that the instructor will have no doubt as to your understanding it. Always leave with each exercise enough space for the comment of your instructor. This is where your personality and his come closest together.

D. Summary.—With each recitation send in a summary of the lesson, telling in your own words what it is about.

E. Personal Problem.—With each lesson make a brief statement of the difficulties, if any, which you meet in the preparation of the lesson. This enables the instructor to make suggestions to your advantage.

Lesson Aid

It is important that the student firmly fix in his mind the three great groups of rocks—Igneous, Sedimentary and Metamorphic. Study the characteristics of each

so as to be able to identify them. Also, fix firmly in your mind the principal kinds of sedimentary, igneous and metamorphic rocks as given on pages 36, 50 and 55, and the methods by which they were formed. The origin and mode of deposition of a clay, for instance, will often determine whether it is of commercial value without the necessity of any further tests.

The author's classification and explanation will be easily understood.

Questions

1. Define (*a*) geology, (*b*) physical geology, (*c*) historical geology, (*d*) rock, (*e*) rock formation.
2. Into what three great groups are rocks divided?
3. Discuss the general characteristics of sedimentary rocks. Where are they deposited?
4. Give a classification of the more common kinds of sedimentary rocks.
5. What are (*a*) sandstones, (*b*) shales, (*c*) loess, (*d*) limestones, (*e*) diatomaceous earth?
6. Discuss the general characteristics of igneous rocks.
7. Discuss the modes of occurrence of igneous rocks.
8. What is the meaning of metamorphism? What are the agencies of metamorphism?
9. Give the principal kinds of metamorphic rocks.
10. Is slate derived from igneous or metamorphic rocks?

COÖPERATIVE RESEARCH IN CERAMICS[1]

By A. V. Henry

Recently there has been an agitation to inject into our ceramic schools more phases of an industrial nature, and to stress product rather than materials. Without a doubt, courses were primarily inaugurated in our universities for the definite purpose of aiding the manufacturer, and to be the means of producing better claywares. However, our institutions are seemingly drifting more and more to scientific problems, and since there is a limit to the amount of work that can be given in a four-year period, manufacturing difficulties are neglected. This is due, in part, to a lack of coöperation and a mutual indifference between the school and the producer. The ceramic schools quite frequently create the impression that the only contact they desire is one for donations or material assistance. The scientific investigations conducted in schools, especially as reflected in theses, are, to the manufacturer, somewhat abstract. He is unable to see how these can help him in making better wares. Therefore, he assumes schools and everyone connected with them to be theoretical, and it is with misgivings that he places in them any confidence whatever.

The manufacturer feels that he has done his full duty when he has aided in the establishment of our schools. He does not appreciate the fact that his interest is required continuously in order for the schools to give him maximum benefit. How should this interest be expressed? It probably can be summed up in one word, "coöperation." The schools should receive suggestions from the producer and give their best thought to commercial problems, for, apart from the practical benefit to be derived from such service, they would be affected advantageously by keeping abreast of practical ceramic

[1] Presented at the Summer Meeting, American Ceramic Society, Toronto, Canada, July 9, 1925.

development. Quite often practices in plant control are in use that are not the most efficient and often are not observed by the superintendent who is in daily contact with the conditions prevailing at his plant. Therefore, it is always advisable for any industry to have its methods examined periodically by a disinterested engineer. Here the ceramic engineers, employed by the schools, can be used to advantage.

Manufacturers should welcome students studying ceramics in their factories during vacation periods. By so doing, the student becomes acquainted with commercial conditions and at the same time is placed in a position to specialize in the industry in which he is most interested. The manufacturer also has an opportunity to take part in his actual training and to observe his qualifications before engaging him permanently. The average student has a three-months vacation yearly and normally spends his time in work, mainly for the purpose of assisting himself financially. It can readily be seen that it would be far more advantageous from all standpoints for the prospective ceramist to devote this time in a position where his ceramic knowledge would be broadened. The practice of employing undergraduates would make comparatively easy the problem of acquiring suitable men and would eliminate to a large degree the dissatisfaction often expressed with ceramic graduates.

A very concrete method of obtaining mutual interest and benefit is through the medium of coöperative research. Every community has problems of a distinctive nature, the solving of which would be to the advantage of some corporation or company. In a coöperative agreement, the corporation or company specifies the problems to be considered, sponsors and finances them, and the work is supervised and conducted in the various departments of ceramics. Where the problem is of any magnitude, sufficient ceramic engineers are employed to relieve the department of all but supervisory work. In the past such problems have generally been limited to government bureaus. At present, however, problems are so numerous and varied that the schools can quite properly assume a portion of the burden.

What benefits may the school and the producer expect to derive from coöperative research? The benefits are many and these are factors in the success of our educational institutions. Schools with modern laboratories are now found in most of the ceramic centers and all maintain on the faculty, engineers who are familiar with the materials and conditions that are often peculiar to the section. Due to this specialized knowledge, problems affecting the ceramic industry can be efficiently studied in our department laboratories.

Fire to be kept alive must be continuously supplied with new fuel. It is just as true that the alertness of our instructors must be kept alive to the ever changing science of ceramics by such means as coöperative research. Since the training of our students is dependent upon the training of the instructors, it is essential that they be kept in constant contact with the industry. When practical phases of production are being analyzed in the school, the student is better able to correlate the teaching that he receives with products and practice. The environment is then conducive to a wholesome commercial education. The school becomes a well-rounded combination of class room and work shop.

Considered from the viewpoint of the producer, coöperative research is an economical and efficient method of attacking problems. By this means he not only has well equipped laboratories, in which his plant operations can be simulated and scientifically studied, but also the services of men who are specialists in this work. Anything that helps to improve a school helps to improve the industry, for, after all, the student of today is the producer of tomorrow.

Our schools could well be interested in problems affecting the development of the ceramic resources of our country. The manufacturer has his own difficulties in plant

control and therefore does not concern himself with the more general burden of explorative research. Especially in the South and in the West are there vast deposits of materials of great promise which still lie untouched and unknown. How many of our ceramic engineers are familiar with the extensive deposits of sedimentary kaolin or fullers' earth throughout the South? Probably all of us know in an abstract way that there are such deposits, but few know any of the details concerning them. To throw more light upon these clays, the Ceramic Department of the Georgia School of Technology has recently entered into a coöperative agreement with the Central of Georgia Railway. The sedimentary kaolins found in Georgia in vast beds throughout an area of approximately 5000 miles are being studied to extend their logical use in the manufacture of refractories, whiteware bodies and as fillers for paper, rubber and oil cloth. Prior to the last few years, little has been done to classify these kaolins and to determine which of them is best suited to a definite purpose. Very often Georgia clays have been judged as a whole from experiences had from a single deposit, which probably did not represent the best for the purpose intended. These clays, as well as many others that are easily available in the country, should be better understood, more properly selected, refined and blended. The assistance of the schools, with the coöperation of those interested in ceramic development, can well be used for this purpose. The school, then, not only serves the industry but improves itself.

CERAMIC EXTENSION EDUCATION AT IOWA STATE COLLEGE[1]

By Paul E. Cox

Introduction

Iowa State College has several extension departments which handle short courses, certain types of night school courses, lectures, exhibitions and other activities that need collegiate direction but which are not any part of regular teaching work. The Division of Engineering has its Department of Engineering Extension, and the ceramic extension educational work is done under the direction of that Department.

Short Courses

For some years there has not been a regularly organized short course in ceramic engineering instruction. There has been no real demand for it, because older men directed the industries of the state and these men had gotten to the stage where the office and sales jobs held their interest. As would be expected a crop of younger men is now out in the plants and the Engineering Extension Department is being asked to supply a definite short course of the type commonly offered by departments of ceramics. Only heavy clay products are manufactured in Iowa, so it is probable that the short course will deal with kilns and driers, scumming, die troubles, lamination troubles, and clay winning equipment, and similar related topics.

While the Engineering Extension Department has sponsored meetings called short courses, these have for some years really been the annual meetings of the Iowa Clay Products Manufacturers Association, though no outsider has been denied admission, and the attendance has always been gratifying.

Since the college was called on for the lecturers, these meetings have been educational, and therefore extension work. Generally the speakers were from the faculty of Iowa State College. Last year the keynote of the meeting was the thing being urged

[1] Read at the Summer Meeting, American Ceramic Society, Toronto, Canada, July 9, 1925.

by many business men; the lecturers talked on practical economics; an out-of-town speaker talked on "Coaching in Business"; while men on the campus talked on accounting methods, business cycles, letter writing, state resources and like topics. No attempt was made at all to discuss plant problems.

The previous year the talks were all on plant problems, and the Ceramic Department presented the results of tests on washed Iowa screenings used to fire Iowa clay hollow building tile by the system best known as the Boss System. Other papers dealt with management problems in the plant, both men and machines being discussed in several papers.

These statements serve to show how the Engineering Extension Department puts across some teaching work while bringing an important group of Iowa business men to the campus. Certainly there are indirect benefits educationally to these men.

Popular Lectures

For five years the Engineering Extension Department has sent out the writer with a portable potter's wheel and a popular lecture on pottery of interest to the Women's Clubs. The wheel has become so obsolete that few people have seen this device but upward of fifty Iowa towns have had this feature of ceramic extension education carried into their lives.

These lectures have dealt generally with ware of interest to the home makers, both white table ware and ornamental pottery. These lectures dealt, however, with the maximum possible amount of technical matter possible to put across in such gatherings. The reactions should be decidedly favorable to the spread of interest in ceramic education, since few people are at all acquainted with the fact that ceramic engineering instruction work has been organized and has reached middle age almost. Indeed, few people can define ceramic engineering and in most of the fifty Iowa towns a new word became a part of the vocabularies.

In many cases, however, the writer has been invited to talk before business men's gatherings and the wheel was merely incidental to solid discussions of possibilities of Iowa clays and shales for additional uses. In one Iowa town the writer has talked before four business men's clubs and one women's club, and certainly something like 500 persons learned for the first time the breadth of the field of ceramic education and products. It should be grasped that Iowa has not the richness of clay manufacturing plants that some other states enjoy, so that such barn-storming tactics fit the circumstances out this way.

The wheel was specially designed for the work, and can be set on a table, opened up, and put to work in ten minutes after arrival in the lecture place. It might be of interest to note that the "village cut-up" always knows exactly how to run the wheel and on trying clowns the act, and makes the hippodrome ending that leaves good nature.

Visual Instruction

Many of the large clay working, glass working and other ceramic products organizations keep reels of excellent quality in the hands of the Engineering Extension Department and such reels as the Lenox, Inc. film, Mason City Brick and Tile Co. films, certain Ford Motor Co. films and others are always out and being shown by all kinds of clubs, schools and like organizations. Indeed it is difficult to have some of the better of these ceramic industry films for use in work on the campus, because they are so seldom at home. The writer has been surprised to find the interest so great on the part of manual training school teachers in ceramic industry films and it must be stated that the very cordial interest on the part of the Engineering Extension Department staff in the work in the

Department of Ceramic Engineering, the cordial wish for a good-sized department at Ames in the field of ceramic engineering, have contributed to this growth in the use of films on ceramic topics. Certainly manufacturers of clay products could very well add to their advertising by furnishing films on the more spectacular features of their businesses.

Women's Clubs

Out in Iowa as well as in other states the Women's Clubs have staged a very large number of programs on ceramic products. They have done this of their own volition, and any extension work done by the college has been done because some woman has been asked to deliver a talk on some kind of pottery she never saw or heard of and so she wrote to the nearest place she could think of for help. The library at Iowa State College has added a very considerable number of books on ceramics due to this club-woman interest. These books are of course of the type that deal with artistic pottery. A traveling collection of the best of American art pottery goes about and is replenished from time to time, the management of this being done by the women. Many women thus see well-designed ware, properly decorated, and purchase according to their means. Such educational work cannot but increase the demand in all ceramic lines for better ware, and to match up with a fine piece of Newcomb pottery, Rookwood pottery, or Marblehead, or any of the others of the excellent types sent out in this collection, sooner or later a good brick house will result, or a tiled floor or other ceramic products. These women are therefore doing thousands of dollars worth of advertising of the best sort of education in ceramics.

One enthusiastic woman in Des Moines took this interest in American studio and small factory pottery over to Paris and managed to impress the idea on the American colony in Paris. The result is that American ceramic products, not only pottery but all good ware, are being discussed across the water. It is but fair to state that this lady got her interest aroused through Iowa State College extension work.

Iowa State College offers work in modeled pottery to the women of the Home Economics Division, the work being done in the ceramic engineering laboratories. Most of these girls marry, build homes and will surely know fired clay all the better for having made a little of it themselves. They are taught the value of tile, of color due to proper firing of clays, of table service, and as they are working under the direction of a first-rate artist, who specialized in art pottery, they become customers without doubt for ceramic ware of the better sort, and so we look on this activity as an extension activity as well as an activity that yields a credit hour or so for girls taking work in household economy.

Exhibitions

Iowa State College takes an active interest in the State Fair and the Ceramic Engineering Department has always been active in furnishing some sort of educational exhibit. One year a very pretty young woman stuck to the task until she could operate the potter's wheel, and being pretty, skilful and pleasant, the Ceramic Department ran away with the honors. Another year an electric kiln was set up and operated and miniature drain tile were made and fired by a student demonstrator. Since Iowa leads the world in the production of drain tile this feature proved of interest. It should be pointed out that education was the purpose and these demonstrators talked about ceramic engineering and what it stands for, while they got the crowd with the tricks. Similar stunts each year are worked up, with student helpers to do the work. Refractories were featured once, paving brick another time, and so on.

On the campus frequent shows are made when gatherings of farmers are at hand, and efforts are always made to tell strangers by exhibitions, demonstrations, etc., exactly

how important a popular knowledge of the field of ceramic engineering is to all classes of people.

Conclusion

It is safe to state that fully half the effort at Iowa State College is given to what is really extension educational work, in those departments that serve in any way ceramic fields. Not only does the Department of Ceramic Engineering do this but it is ably and heartily supported in many ways.

VOCATIONAL TRAINING IN CERAMICS[1]

By Ross C. Purdy

By vocational training we mean training of the student's mind in the use of knowledge; a practice in application of science fundamentals to the problems encountered in a given job. In contrast with collegiate training, vocational education is of an intermediate grade; it ranks in character and grade with the school intermediate between the grammar and collegiate schools known on this continent as High Schools. A vocational course of classroom and laboratory instruction of high school quality and breadth is directed entirely to preparing the student's mind for a better understanding of the underlying scientific principles of his chosen vocation.

Vocational training need not and very often does not include manual training except in so far as manual exercises are necessary in the laboratory to demonstrate the application of the principles and theories developed in the classroom.

Vocational education may be provided in several forms. The vocational education curricula and schedules differ according to convenience and necessities of the students and the availability of facilities.

Two-Year University Industrial Course

The first classes organized by Prof. Edward Orton, Jr., in 1895, were two-year courses of intermediate grade. The prerequisites for admission to this two-year or industrial course were two years industrial experience or graduation from high school for those under twenty-one years of age and practical experience in ceramics for those over twenty-one years of age. Some there were who took this two-year industrial course who had not completed their grammar school training. It was essentially and in fact a vocational course of instruction in that it prepared men for a ceramic vocation; it was limited to preparing pupils for service in the industries and did not aim to give what is generally called higher education, that of collegiate grade. This short or industrial course was continued successfully at Ohio State University for seventeen or more years and several who are now among the most prominent ceramic technologists were graduates of this two year industrial course and had no other school training in ceramics. Three of the Directors of collegiate ceramic departments in the States had no collegiate training other than this industrial course. It was a vocational course of instruction and the results obtained warrant serious consideration of whether the universities should not again give a two-year industrial course.

Midwinter Two Weeks' University Course

Another scheme for vocational training is that which is known as "short winter schools." Being the originator of this vocational educational scheme and having begun it at University of Illinois where it has been continued successfully,

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[1] Presented at the Summer Meeting, American Ceramic Society, Toronto, Canada, July 9, 1925.

though intermittently, since 1905, I present it for your consideration with considerable pride and with lots of assurance of its value. I am now associated in manufacturing with a ceramic engineer whose only school training other than in one of these two weeks winter courses at the University of Illinois was in the three Rs at a country school. He is now able to calculate molecular formulas and he has developed charts in process control schemes that involve pressures, volumes and weight relations. He is educated in ceramics; self-educated, it is true, but he got his thought direction and methods in those two weeks of University vocational training.

Other universities on rare occasions have given short winter courses of lectures and laboratory exercises open to any who would enroll. Iowa State College is planning to have such vocational courses. The holding of these short term schools in the winter is recommended for serious consideration by universities. Ceramic organizations should urge and support them. They provide a vocational training to many factory employees who otherwise would have no opportunity to obtain a systematic start in the finding and using of those scientific facts which have applications in ceramics.

Summer Courses

Professor Binns at Alfred University has for several years conducted a vocational school. Classes in the technology and laboratory demonstrations of methods of pottery production have been given in these summer schools. Professor Binns has not made these vocational courses generally known to factory employees, hence the majority of the pupils attending are art school teachers. For any one who intended to have pottery making as a vocation, this summer course at Alfred University would be most excellent.

For the three summer months each year our university ceramic departments are idle. Their overhead charges continue as in the winter months. This piles the overhead charges per pupil onto those who attend during the winter, and to the auditors and to those who are responsible for salaries and current expense appropriations this gives a basis for estimating cost of education per pupil, which, from our point of view, is unfair to the winter pupils. It deprives them of adequate instruction and equipment. If the department overhead could be spread over pupils attending twelve rather than nine months the expense per pupil on the auditor's books would appear more favorably.

The scheme of having two summers of satisfactory plant work as a requirement for graduation from a ceramic department is excellent. This should be a requirement in every ceramic school curriculum. This cares for the boys who are taking the collegiate course of instruction, but it is not they who we are now considering. We are thinking of vocational school opportunity for those who can or will not take the collegiate ceramic course.

Would not the disadvantages, if there are any, of having the two-year industrials in the same classes with the four-year collegiate pupils, be entirely met if the ceramic class rooms and laboratories were made available during the three summer months to those who want the industrial or vocational training? Would not this give service and reduce the overhead charges per pupil? A consideration of this by the universities is seriously recommended.

Correspondence Courses

Prof. Greaves-Walker is the first to inaugurate a correspondence course in ceramics. This is commendable and he should have the hearty support of all ceramic organizations and persons. Should we not council with him on making this correspondence course just as effective as possible? He is now and we hope will continue leading in this form of vocational training, that of giving the men in the plant an opportunity in thought direction and methods of fact finding. We pledge him organized assistance if he will make plans for it.

Foremen Institutes This scheme of vocational training has been successful from the standpoint of the foremen. The Ohio State Board for Vocational Education has three lecturers who give instructional courses in factories and industrial centers throughout the state. The Refractories Manufacturers Association for two years sponsored foremen institutes. Some corporations have their own schools with a full time staff of instructors.

A scheme for a coöperation between universities and ceramic associations on a definite schedule of institute meetings in different ceramic centers is recommended for consideration by both the universities and the associations of ceramic manufacturers. This suggestion is in line with those for university extension in ceramics which Professor Watts will present. If foremen institutes are established and thoughtfully cared for they possibly will result in providing for itinerant ceramic lecturers sponsored by and going out from the several ceramic schools.

High Schools The Smith-Hughes law provides for day-time schools, night schools and part-time schools. If a local school board will provide the room and equipment the federal and state governments will assist in the financing of instruction. A ceramic night school has for two years been operating in Newell, W. Va., under the direction of A. V. Bleininger. The Ohio Ceramic Industries Association has petitioned the East Liverpool school board to establish at once a night school and as soon as possible a day school in vocational ceramics. The State Vocation Educational Board has guaranteed very substantial financial aid. Professor Watts has offered the coöperation of the Ohio State University Ceramic Department. The establishment of a ceramic school in East Liverpool High School is well nigh a fact and the Ohio Ceramic Industries Association is planning to secure similar schools in other ceramic centers throughout the state.

The farmers have taken advantage of the provisions in the Smith-Hughes act with the result that in Ohio alone over $700,000 is spent annually by the federal and state government in university extension in agriculture. The ceramic manufacturers need only to present a claim to the state boards and legislature to secure financial support for vocational education in high schools, in those cities where the ceramic interests can justify the local school board in using city school funds to provide the facilities.

Other schemes for vocational training will suggest themselves by local or group requirements and conditions. Those which we have here considered are:

1. Two-year industrial courses at universities.
2. Midwinter short courses of two or more weeks.
3. Summer schools in universities.
4. Correspondence courses.
5. Foremen institutes.
6. High school courses, day, night and part-time courses.

DISCUSSION ON "AN X-RAY STUDY OF NATURAL AND ARTIFICIAL SILLIMANITE"[1]

N. L. BOWEN AND J. W. GREIG:[2] In the July number of the *Journal* a paper by John T. Norton deals with "An X-ray Study of Natural and Artificial Sillimanite." The "artificial sillimanite" is of course mullite

[1] J. F. Norton, *Jour. Amer. Ceram. Soc.*, **8** [7], 401 (1925).

[2] Recd. July 13, 1925.

($3Al_2O_3.2SiO_2$) and not sillimanite ($Al_2O_3.SiO_2$) at all, and Norton's results confirm Wyckoff's observations that mullite and sillimanite powders give indistinguishable X-ray patterns. Wyckoff's observations to this effect were published by us in the original paper where the compound $3Al_2O_3.2SiO_2$ was first definitely recognized and described.[1] Wyckoff has since extended his studies to individual crystals but his results have not yet been published.

In his conclusions Norton states: "The only other conclusion is that the two compounds are identical and this is in direct contradiction of the accurate chemical analyses of Bowen and Greig. It seems as if the X-ray method of analysis was a more fundamental method of determining the nature of a substance than a chemical method in this particular case because the results are properties of the crystalline phase only, and are not upset in any way by the amorphous glass in which these crystals occur or which they may include." Plainly Norton leans toward the opinion that sillimanite and mullite are identical, and if the above-quoted remarks were an accurate picture of the situation the matter might be allowed to rest there. It is, however, by no means a question merely of the relative reliability of X-ray analysis and chemical analysis. We did indeed give chemical analyses of crystals of mullite by way of confirmation of our conclusions, analyses, which, by the way, were made upon free crystals formed in "pipes" of electric furnace melts and which were determined by microscopic examination to be all but free from foreign contamination of any kind. But the establishment of the fact that the compound of alumina and silica stable at high temperatures (mullite) has the composition $3Al_2O_3.2SiO_2$ did not depend primarily upon chemical *analysis* at all but upon *synthesis*. Working with pure alumina and pure silica we found that the 3:2 mixture was the only mixture that could be induced to form a single, homogeneous, crystalline phase. All other mixtures formed the same crystals, with no variation in their properties, together with another phase representing the excess material, and in this respect the 1:1 mixture was no exception. Such evidence of the composition of a compound is complete and final. It needs no analysis of any kind to support it, though confirmation upon that side can do no harm.

It may be pointed out here that two organizations, the Bureau of Mines Experiment Station at Seattle and the Norton Company of Worcester, working independently of each other and of us upon the *synthesis* of "artificial sillimanite" obtained results that confirm our conclusions. They were unable to explain their results in the light of the belief then current that sillimanite ($Al_2O_3.SiO_2$) was the compound formed, but their difficulties fell away with the appearance of our results establishing the composition of the compound as $3Al_2O_3.2SiO_2$.

[1] *Jour. Amer. Ceram. Soc.*, **7** [4], 253 (1924).

The difference of chemical composition between sillimanite and mullite is unquestionably clearly defined. In physical properties they are in many respects remarkably alike, yet in most respects measurably different. The refractive indices differ by amounts that are several times the error of measurement on even very small crystals. In thermal behavior they are quite different. Mullite is altogether unaffected at any temperature up to 1810°C, whereas sillimanite, at any temperature above 1545°C, is decomposed into mullite crystals and a highly siliceous liquid. This fact is remarkably difficult to explain upon any hypothesis of the identity of mullite and sillimanite since it would involve the obvious impossibility of a compound breaking up into itself and something else.

In crystal angles and direction of cleavage mullite and sillimanite approach each other more closely than in any other physical properties. Of all properties these are, perhaps, the most intimately connected with the atomic arrangement. Their X-ray diffraction patterns, which furnish a more direct means of deducing atomic arrangements, are indistinguishable. Must we conclude, therefore, in the face of all the evidence of differences, that they are identical, or should we conclude that they are merely so similar in atomic arrangement that they are scarcely distinguishable in crystallographic properties and indistinguishable in X-ray diffraction patterns?

GEOPHYSICAL LABORATORY,
JULY, 1925.

A DESCRIPTIVE BIBLIOGRAPHY OF SCUMMING AND EFFLORESCENCE[1]

BY F. G. JACKSON[2]

Introduction

The words "scumming" and "efflorescence" are often confused in ceramics and are frequently replaced by local terms such as "kiln white," "whitewashing," "petering," etc.

The generally accepted meaning seems to be:

Scumming—The formation on the surface of a ceramic body of a deposit of foreign matter during the process of manufacture.

Efflorescence—The formation on the surface of a finished ceramic ware of a deposit of foreign matter due to exposure to weather.

In the following abstracts from the literature the development of understanding of the various causes leading to these blemishes has been traced.

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[1] Published by permission of the Director, U. S. Bureau of Mines, Department of Commerce.

[2] Associate Chemist.

Whenever a new thought on the subject has been published, this is given fully below. Otherwise only the nature of the article is given.

A study of the literature begins of necessity with "The Collected Writings of Hermann A. Seger." The small amount of work published previous to his time is now buried in obscurity in inaccessible German trade journals and technical papers. Seger reviewed these and added so much of interpretation and explanation as well as new material that it may well be said that the foundations of ceramics as an exact science were here laid.

The literature since Seger's time has been traced in the following publications. Those marked * have been completely searched through 1924.

List of Publications

Baumaterialienmarkt. Leipzig, Germany.
***Brick.** 407 S. Dearborn St., Chicago, Ill.
***Brick and Clay Record.** 407 S. Dearborn St., Chicago, Ill.
Brick and Pottery Trades Journal. London, England.
Brick Builder, The. Boston, Mass.
British Clay Worker, The. 43 Essex St., Strand, London, England.
Builder's Journal, The. England.
***Bulletin of the American Ceramic Society.** Columbus, Ohio.
***Burning Clay Wares.** By Ellis Lovejoy. T. A. Randall & Co., Indianapolis, Ind.
Canadian Clay Worker, The. 32 Colborne St., Toronto, Canada.
***Ceramique, La.** 84 rue d'Hautville (X), Paris, France.
***Ceramique Industrielle, La.** By A. Granger.
***Ceramic Abstracts.** Columbus, Ohio.
***Ceramic Industry.** 407 S. Dearborn St., Chicago, Ill.
***Ceramist, The.** 170 Roseville Ave., Newark, N. J.
***Clay Record.** Chicago, Ill. (Combined in 1911 with **Brick.**)
***Clay Worker, The.** T. A. Randall & Co., Indianapolis, Ind.
Deutsche Toepfer und Ziegler Zeitschrift. Halle, Germany.
Eidgenossen Materialsprüfunzsanstalt in Zurich. Switzerland.
Engineering News. McGraw-Hill Book Co., New York, N. Y.
German Patents.
Industrial and Engineering Chemistry. 17th St. & Penna. Ave., Washington, D. C.
***Journal of the American Ceramic Society.** Columbus, Ohio.
Journal of the Franklin Institute. 15 S. Seventh St., Philadelphia, Pa.
Keramische Rundschau. Dreystr. 4, Berlin, Germany.
Ohio Mining Journal, The. Columbus, Ohio.
Ohio Valley Manufacturer. (Cannot be located.)
Pottery Gazette, The. 8 Broadway, Ludgate, London, E. C., England.
Revue des Materiaux de construction et de Travaux Publics. 148 Bvd. Magento, Paris, France.
Revue Scientifique.
***Sprechsaal.** Coburg, Germany.
***Tonindustrie Zeitung.** Dreystr. 4 Berlin, Germany.
Thonwaaren Fabrik. Stuttgart, Germany.

* Journals have been checked through 1924.

Trade Journal Review, The. England.
***Transactions of the American Ceramic Society.** Columbus, Ohio.
***Transactions of the Ceramic Society.** Stoke-on-Trent, England.
University of Illinois Bulletins. Urbana, Ill.
Zeitschrift Offentliche Chemie. Plauen i.V. Germany.
Ziegel und Bau Industrie.
Ziegel und Cement. Berlin, Germany.

Abstracts of Literature

The Collected Writings of Hermann A. Seger. Vol. I.

P. 108. A large amount of lime in a clay, containing several per cent of iron, will change the red color ordinarily derived from iron oxide to yellow.

P. 127. Such clays (containing much lime) absorb sulphur compounds freely from fire gases and form calcium sulphate and then the normal red color of iron appears. At a high temperature the red is destroyed and the color returns to greenish yellow. Under reducing conditions calcium sulphate is decomposed at lower temperatures than under oxidizing.

P. 213. Experiments are described where the water in kiln gases was withdrawn, condensed and analyzed from kilns burning wood and gas. "The acids and salts remain in the body or unite with the basic substances of the body as the alkalis, lime, magnesia, ferric oxide, and alumina and bring them to the surface as salty incrustations which later on at a higher temperature are decomposed again more or less and give rise to disfiguring efflorescence or a thin glaze. The alkaline salts are very active in the presence of acids. Ammonium chloride will form other volatile chlorides, thus transporting bases to the surface."

P. 272. The first tunnel drier has just been announced. Seger considers its use fraught with perils.

P. 313. Studying the water-smoking of a gas-fired continuous kiln in which gases from chambers containing ware under fire were drawn over green bricks. He found that the bricks sweated "and every brickmaker knows the consequence. There is produced on the surface a whitish, firmly adhering coating..... On examining the efflorescence with a magnifying glass, it will appear as wart-like or scaly or blistering masses quite similar to those found on air-dried brick and whose characteristics disappear gradually only when the clay has assumed the vitreous condition. Of what nature this efflorescence is has not yet been determined by chemistry. Microscopic examination shows it is not ash, but that it is composed of residues partly crystalline which, at one time in solution, have been deposited by the evaporation of water on the surface of the brick. It may also have been caused by the water taken from the clay in water-smoking. Salts which can do this are plentiful, $CaCO_3$, $CaSO_4$, NaCl, and FeS decomposing to form $FeSO_4$, $Al_2(SO_4)_3$ and $MgSO_4$. Also NH_4 salts, alkali salts, H_2SO_3 and H_2SO_4 are condensed from the fire gases and form soluble salts on the surface of the brick."

P. 351. "All the substances which are taken up from the fire gases are concentrated near the surface, and hence all sorts of colors are often blended, while the color of the interior shows a certain uniformity."

P. 354. Analyses are given of the surfaces and cores of yellow bricks with red surfaces and the amount of remaining calcium carbonate in each is calculated from the amount of sulphuric acid present. The ratio of calcium carbonate to iron oxide is very low in the red parts and high in the yellow.

P. 357. Drying efflorescences mostly occur on bricks with smooth dense surfaces. On rough surfaces and on lean and porous clays the water evaporates from within as well as on the surface and thus the soluble impurities are not brought out. "Since in many cases these efflorescences are produced only in water-smoking, and only when water vapors condense on the brick, they may often be prevented by conducting the water-smoking very carefully."

Efflorescences appearing only after manufacture are classed separately. They tend to destruction of the ware, and consist of sodium bicarbonate, sulphates, especially soda and magnesia, chlorides, etc. There is also the effect of organic growths.

P. 366. He describes the greenish or yellowish green efflorescence due to vanadic acid and says that this can be avoided by reduction.

P. 369. He covers the formation of sulphuric acid on the surface of the ware, the consequent formation of soluble sulphates, and the consequent formation of scum in the kiln, efflorescence in service, and destruction of ware by repeated recrystallization. Reduction during firing is his sovereign prescription.

P. 381–4. Yellow and Green Efflorescence on Brick Fronts. Buff burning clays are well suited for terra cotta but often take on an undesirable color on exposure, becoming yellow to blue green and later brown to black. This is often due to vegetable growth but sometimes is a salt. Dr. Cohn believes it is iron, others have suspected cobalt, Seger proved a green efflorescence on a buff brick was chromium. He reports here a golden yellow coating as vanadic acid. A water extract gave the characteristic color changes.

P. 385. Vanadium Compounds in Lignite Clay. He collected and analyzed a sample of green efflorescence, finding 29% vanadic acid. He has found that reduction at high temperature causes the vanadium to fuse so that it cannot form scum.

P. 396. The use of barium compounds to prevent scum is fully covered. The precipitation of sulphates with carbonate, the need of an excess, and the harmlessness of that excess are shown. With barium chloride non-soluble salts are formed and the excess must be avoided. When large amounts of sulphates are present, barium chloride is not recommended.

1877 Aron, Dr. Salt efflorescence on brick. *Tonind. Zeit.*, **1** [19], 147.

Analysis showed 42% sodium sulphate in a gray scum. This serves at higher temperatures as a flux to sinter the ware. Repeated recrystallization will destroy the brick structure.

1877 Cohn, W. On the artistic coloring of ware. *Tonind. Zeit.*, **1** [26], 207.

Describes experiments on dipping wares in solutions of iron salts before firing and varying firing conditions. Can get red, yellow, or green colors. The presence of lime has a bearing. Samples had green efflorescence which he proved was an iron salt.

1877 Anon. Yellow and green efflorescence. *Tonind. Zeit.*, **1** [47], 378.

Question: what is the nature of it?

Answer: see Seger, *Tonind. Zeit.*, **1** [46], 368. (The original of Collected Writings, I, 381–90.)

1878 Trautwine, Wm. Incrustation on brick walls. *Jour. Franklin Institute* [105], 259.

Studied bricks which effloresced in service. He found magnesium, calcium, and ferrous sulphate in bricks fresh from the kiln. The bank clay contained no carbonates or soluble salts, but lime and magnesia, presumably as silicates, in about the same amounts as in the fired ware, suggesting the inference that in some cases firing may con-

vert all or nearly all of the magnesium silicate to sulphate. The process of firing bricks with coal accounts for this. Coal contains pyrites which burn to sulphurous acid gas. When this gas, air, moisture, and substances having an affinity for sulphuric acid are brought together at high temperatures long sustained, sulphates are formed.

1878 PEMBERTON, H. On the evil effects arising from the use of dolomitic lime in building brick walls. *Jour. Franklin Institute* [106], 52. Reviewed *Tonind. Zeit.*, **3**, 178 (1879).

Efflorescence may be caused by Mg compds. in clay converted to $MgSO_4$ by S from coal. Second, lime in mortar absorbs sulphur from combustion products in the air of cities and forms $MgSO_4$. This is dissolved by rain and concentrated on the surface. This solution makes the mortar fall out. Magnesian lime is much used to make mortar. It is preferred by the brick layer.

1879 ANON. Efflorescence on brick. *Tonind. Zeit.*, **3**, 38.

Question: What are markings on the bricks sent?

Answer: White powder is $CaSO_4 + MgSO_4$. Crystals are gypsum, red-brown scum is iron oxy-hydrate, yellow-green stains are vanadium.

1879 ANON. Cause and removal of white efflorescence. *Tonind. Zeit.*, **3**, 54.

Question: How to remove a white efflorescence from a church when Portland cement mortar was used?

Answer: Wash with dilute hydrochloric acid followed by water.

1879 ANON. Yellow-green efflorescence on brown-coal clay brick. *Tonind. Zeit.*, **3**, 129.

Question: Could not make Seger's test for V work well on yellow-green stains unless very plain ones. Finds most V stains on brick in spring when they have stood out all winter. Is this due to moisture?

Answer: (by Seger) Some V salts are colorless and some are insoluble. Effect of moisture on soluble salts fully explained.

1880 ANON. White scum on red bricks. *Tonind. Zeit.*, **4**, 312.

Scum is due largely to Na_2SO_4 and $MgSO_4$, these both very soluble in hot water, slightly in cold water. If cold water is used to temper and bricks are dried fast in a cold air blast and properly fired (so that during water-smoking they do not become wet again) they will not scum. If dried by heat and little draft they will. Workmen's finger prints on bricks show as scum because the heat of the body has dissolved the salts.

Answer: $CaSO_4$ also plays an important role in scumming. Solubilities quoted. Maximum solubilities around 35°C. Finger prints cannot be due so much to temperature as to pressure and oil on the fingers.

1880 ANON. White scum on red bricks. *Tonind. Zeit.*, **4**, 422.

Question: Water-smoking seems unequal in different parts of kiln. Resets put in unfavorable places will scum. What is this and how prevent it?

Answer: Principally calcium and magnesium sulphates formed by condensed water and acids in smoke. Draw plenty of air through the kiln, have no dead air pockets and heat slowly.

1885 ANON. White scum on brick. *Tonind. Zeit.*, **9**, 378.

Question: Brick from ring kiln burning hard coal are almost always scummed. I want to try peat. Will it help?

Answer: Scum is due to condensed moisture on ware. Can be prevented with care. Peat contains more water, therefore needs more care.

1886 SEGER'S LABORATORY. Analysis of effloresced salts. *Tonind. Zeit.*, **10**, 400.

Sample showed

K_2SO_4	32.38	water soluble
Na_2SO_4	26.83	
$CaSO_4$	0.60	
$CaCO_3$	5.32	acid soluble
$Fe_2O_3 + Al_2O_3$	0.52	
Insoluble residue (sand)	34.35	

1886 EDITORIAL. Efflorescence on brick. *Clay Worker*, Jan.

"We have little disposition to enter into discussion of the many papers being published on this subject. We desire, however, to publish the several theories, observations, and experiments that come to hand and avoid injury to any but aid in the truthful solution of the real cause or causes.

"The following was read by J. C. ANDERSON before the Illinois Society of Architects:

" 'The substances of this wall coating I find to be essentially the sulphates of magnesium, soda and potash. These do not come from the face brick; this applies to several makes; the main cause of the evil lies in the magnesia in the lime of the mortar.

" 'The common bricks are made from drift clays containing pebbles high in magnesia and iron pyrites. The face bricks are from a clay containing little of these. In firing common bricks the sulphur is eliminated and converted into sulphuric acid and absorbed by the brick at a red heat. It unites with the alkalis and alkaline earths, forming salts. These bricks are saturated with water before laying. In drying, the salts are carried through the face brick to the outside and crystallize there.' He advises pure mortar for face bricks, isolating the front wall from the rear wall, using as little water as possible in construction, protecting from rain during construction, and use of projecting drips.

"Wm. E. HINCHLIFF replies to this in the *Chicago Tribune*, Dec. 11, 1885 (?):

" 'I will agree with the gentleman when he says that this subject has received little notice in this city until 'very recent years' for there was no problem here until the Anderson Pressed-Brick Co. began to manufacture. The trouble is in his clay which shows magnesia in plenty.' Disclaims A's championship that deposits are restricted to no particular brick. Some may show it and it is their fault. Why are Anderson bricks covered with whitewash oftentimes before leaving his yard or even his kiln if the trouble is with the mortar? This has been seen by many witnesses. Differs also as to remedies. Advises painting the bricks.

"F. P. MAYERBERG writes to the *Clay Worker:*

" 'Mr. Anderson should have said 'The evil is in existence since insufficiently burned brick made of heavily charged alkali clays were laid in walls exposed to all changes of weather.' All of the prominent terra cotta manufacturers have met the same trouble and overcome it. Their process is too expensive for bricks, but there are cheaper ways of doing it.' "

1886 BROWN, R. T. The composition of whitewash. *Clay Worker*, **6**, 325.

"The white substance that appears on the surface of new brick buildings is carbonate of lime. Lime may exist in clay and not be visible. When it is burned it becomes caustic lime, soluble in water. When the brick absorbs water from the rain, the lime dissolves and is carried to the surface on drying. There it takes carbonic acid from the air and becomes insoluble carbonate. It may be washed off with dilute hydrochloric (muriatic) acid. I know of no way to prevent its appearance, if the clay contains lime."

1887 ANON. Whitewashing of tile. *Clay Worker*, **8**, 175.

"We have received a tile from Mogadore, Ohio, that is heavily whitewashed where fingers touched it while soft. They ask why. We do not know. The whitewash is carbonate of lime or saltpeter or soda deposited in the process of water-smoking."

1888 LOVEJOY, ELLIS. Clays of Fivemile Creek. *Ohio Mining Journal*, **17**, 34.
"Some of these clays effloresce in service very badly. Analysis shows the efflorescence to be sulphate of alkalis with iron and traces of calcium and magnesium sulphates. Explanations previously offered: (1) Sulphur fumes in smoky air from sulphates. (2) Sulphur fumes from burning soft coal in kiln form sulphates. These do not explain why when bricks made from two different clays are fired in the same kiln one kind effloresces and the other does not. Sulphide of iron has been found in some of these clays. When this is fired in an oxidizing atmosphere, it forms alkaline sulphates which are the cause of the efflorescence."

1888 "BACHSTEIN MACHER." To beginners in clayworking. *Clay Worker*, **9**, 23.
"Many bricks are discolored by setting them too wet into the kiln. It will pay you if you set them dry into the kiln."

1888 BAKER, PROF. IRA O. Efflorescence and impervious mortar. *Engineering News*. Reprinted in *Clay Worker*, **9**, 286.
The efflorescence sometimes originates in the brick, particularly if they are fired with sulphurous coal or are made from a clay containing iron pyrites. When the brick gets wet the water dissolves the sulphates of lime and magnesia and leaves them on the surface. Frequently the efflorescence on the brick is due to the absorption of impregnated water from the mortar.

1888 DAVIS, CHAS. T. Exudations upon brickwork. *Clay Worker*, **10**, 278.
Description of appearance and occurrence during wet weather. Repeats explanations already brought forth.
An epidemic of efflorescence in 1882 was discussed at length by members of the Academy of Natural Sciences in Philadelphia. They decided it was sulphate of magnesia formed from magnesia in the mortar dissolved in the presence of water by sulphurous acid from burning coal.

1889 ELSOM, J. F. Efflorescence on brick, its cause and cure. *Clay Worker*, **11**, 18.
A long paper read at the N. B. M. A. convention. Nothing new offered. Discussion brought out that red mortar makes more efflorescence than other colors and buildings put up in wet weather will effloresce badly. Hard-fired bricks effloresce less than soft-fired, rough brick less than smooth.

1889 F. L. H. Touching on efflorescence. *Clay Worker*, **11**, 238.
Attributes efflorescence to dampness in kiln.

1889 BLUCK, R. S. What's the trouble? *Clay Worker*, **12**, 95.
Wants to make a red face brick but gets a very thin greyish-white skim on it. Would like a remedy.

1889 CABOT, SAMUEL. White on bricks. *Builder and Woodworker*. (Reprinted in *Clay Worker*, **12**, 98.)
Finds at least three substances which cause this, carbonate of soda, most common on new work, silicate of soda from salt clays, and sulphate of magnesia. This is formed from pyrites in clay forming sulphuric acid and this uniting with magnesia in the lime mortar. He concludes: "Efflorescence is never due to bricks alone and seldom to lime alone. To avoid it the bricks should be covered with an oily preservative. Linseed oil will not serve."

1890 CRARY, J. W., SR. Water-smoking and reburning kilns. *Clay Worker*, **14**, 262.
All clays that shrink or settle in firing have more or less alkaline salts. If heated too fast or made red hot on the surface before the water is out of the inside part of the

brick the salts effloresce. If the kiln be closed too quickly, or until the whitewash be thoroughly oxidized or burned off, the bricks will have a discolored, motley appearance.

1892 ANON. Efflorescence on brick. *Clay Record*, **1**, 47.

New buildings in Chicago are effloresced. Smoke has much to do with it. Alkali is absorbed by porous brick. Efflorescence results when brick are made from a clay containing magnesium, sodium or potassium sulphate and not sufficiently fired to fuse them. The sulphates dissolve the alkali on becoming wet. On evaporation the white crystals are deposited. Describes tests made at Berlin on brick to determine if they will effloresce.

1892 J. F. E. Efflorescence on brick. *Clay Record*, **1**, 82.

Answer to above. Efflorescence contains carbonates, sulphates, silicates, etc. Generally one predominates but not always the same one. For many causes there can not be one cure. Cause may be in the clay, the brick, the mortar, the season, manipulation, laying. Describes how mortar should be prepared. Advises seasoning it a year.

1893 Discussion at N. B. M. A. convention on whitewashed bricks. *Clay Worker*, **19**, 163.

Question: Will hot air in a drier cause whitewash?

Answer: It was found out nine years ago that $BaCO_3$ would prevent it. Does not know why. Brick set wet in kiln will whitewash. Some very vague ideas expressed as to the theory.

1893 ANON. Efflorescence on brick. *Clay Worker*, **19**, 509.

Advises to do nothing about it but to build the building fairly watertight and it will not give much trouble or last long.

1894 ANON. Discoloration of brick. *Clay Record*, **4** [10], 18.

The writer's common bricks scum. He is water-smoking with wood and firing with three different sorts of coal but cannot prevent scum. Wanted help from N. B. M. A. convention. Proposed a question and is dissatisfied with the answers.

1894 ANON. Efflorescence on brick. *Clay Record*, **4** [12], 27.

Bad cases in Philadelphia after a hard winter and heavy spring rains. Paint and oil suggested to prevent recurrences.

1895 EDITORIAL. Whitewash and efflorescence. *Clay Worker*, **24**, 352.

A plea for investigation of these subjects.

1895 CRAMER. Color appearances of brick when water-smoking, also from artificial drying. *Brick*, **2**, 44. (Translated from *Tonind. Zeit.*)

Drying by direct heat has changed the color of some yellow bricks to gray. Sulphurous gases on wet clay are blamed. Olschewsky says in discussion much trouble comes from drier, not from kiln and much $BaCl_2$ and to $BaCO_3$ is used to the wrong end.

1895 CUMMER, F. D. Reply to above. *Brick*, **2**, 49.

C. did not mention that ware must be wet to have sulphur in drying gases absorbed. Large volume of air should be mixed with kiln gases. This, moving fast, will not allow condensation and corrosion. The writer makes a direct heat drier on this principle which works successfully. He can dry a terra cotta block weighing $15^1/_2$ lbs. wet to 10 lbs. dry in 36 hours without cracking.

1895 OLSCHEWSKY, W. Prevention of scum and discoloration on face bricks, terra cotta, etc. *Ziegel & Cement.* (Translated in *Clay Record*, **9** [10], 16 (1896.)

Translated by Huelsen & Co. as "Petering" or "Whitewashing" in a pamphlet published at Newcastle-on-Tyne. (Reviewed in *Brick*, **2**, 278.)

Gives the following limits:

1. When mainly so-called finger dints are scummed, suspect the water.

2. If scum is all over the face, see if the side against the board in drying is clean. If so, trouble is in clay.

3. If scum only when exposed in kiln or drying, then due to salts in clay, but likely only small amounts.

Barium carbonate will precipitate calcium sulphate.

1895 BENFEY, GUSTAV. Discoloration of face brick and terra cotta. *Brick*, **2**, 358.

Describes occurrence of gypsum and how only a little is dissolved if worked fast. Describes use of $BaCO_3$ and of flour paste (formerly used). Epidemic of whitewash in Chicago blamed on soluble salts washed out of soot on buildings into bricks by a thunderstorm. Citizens had blamed lightning. Describes normal efflorescence on new buildings.

1896 EDITORIAL. Efflorescence on Brick. *Clay Record*, **9** [10], 11.

Opens the subject.

1896 EDITORIAL. Prevention of scum on face brick. *Clay Record*, **9** [12], 19.

Describes and urges use of $BaCO_3$.

1896 DISCUSSION N. B. M. A. convention. "Can brick become stained white or deposit an efflorescence after burning owing to sulphurous coal?" *Brick*, **4**, 87.

Mr. Fiske says sulphur in coal may make the white found on the bricks as they come from the kiln but does not think it has anything to do with efflorescence in the wall. Mr. Ittner agrees.

1896 DISCUSSION, N. B. M. A. convention. "Does slow drying tend to prevent discoloration or whitewashing during burning?" *Brick*, **4**, 89.

MR. ITTNER: "Slow drying is conceded to be ample drying. Thorough drying will prevent discoloration unless it is in the clay."

CAPT. CRAFTS: "If there is scum we say that they were set too wet."

MR. RICHARDSON: "You must not let moisture deposit on the brick at all. Must have a strong draft."

1896 ANON. "Hodge-Podge." *Tonind. Zeit.*, **20**, 588.

Describes efflorescence on walls. Ascribes either to plants (algae) or minerals. Effect of slightly soluble salts lasts longest. Sulphates are the commonest, then carbonates, chlorides, nitrates. Vanadium and molybdenum salts are prominent because of intense green color. Possible sources tabulated. Describes methods of formation of salts and their efflorescence.

1896 OLSCHEWSKY, W. Drying clay wares. German Pat., **87**, 103.

Wares dried in a closed room by $CaCl_2$. $CaCl_2$ solution drains off, is evaporated and used again.

1897 DISCUSSION, N. B. M. A. convention. "Is efflorescence on a brick wall ever due to the kind of mortar used?" *Brick*, **6**, 118.

ORTON: "Red mortar is colored by iron oxide made from copperas (ferrous sulphate) by igniting. The action is not complete and the remaining $FeSO_4$ effloresces."

1897 DISCUSSION, N. B. M. A. convention. "Can whitewash be prevented from coming on the surface of green brick by varying its treatment in a drying tunnel?" *Brick*, **6**, 118.

Orton said he knew of at least four causes. Matter referred to an investigating committee.

1897 DISCUSSION, N. B. M. A. convention. "What is the composition of efflorescence?" *Clay Worker*, **27**, 124.

ORTON: "It is a soluble salt, generally of lime. It is carried to the surface by water in drying. The faster the drying the more efflorescence. There are four or five sources from which it may come."

GATES: Advises slow raising of temperature at first so as to avoid condensation. Sulphur from the fires will adhere to that and burn on it as a scum.

1897 JACOBS, H. L. Water-smoking and its effect on the brick. *Clay Worker*, **28**, 101.

Advocates use of draft in water-smoking.

1897 ANON. Brick efflorescence. *Clay Worker*, **28**, 265.

Prof. Gunther said in an address that efflorescence or incrustation could be prevented by long exposure of clay, by adding barium salts before burning or in continuous kilns by preventing oxidation of sulphur by limiting the air supply.

1898 ANON. Efflorescence on brick and sandstone. *Trade Jour. Rev.* (Reprinted in *Clay Record*, **13** [1], 15.)

Review of subject.

1898 PEMBERTON, HENRY. Discussion of efflorescence. *Trade Jour. Rev.*, **106**, 52.

Blames dolomitic lime acted on by sulphur in smoke in the air.

1898 ANON. A German's opinion of brick efflorescence. *Clay Record*, **13** [7], 19.

A review of Seger's work. Advises $BaCO_3$, reduction and high fire.

1898 GERLACH, O. Saline efflorescence, its cause. *Clay Record*, **13** [8], 16; **13** [9], 16.

A long article. Considers efflorescent sulphates found in clay, oxidation of pyrite to sulphate. Less scum if clay not weathered. Green ware should not stand around. Gypsum in water used. Colorants may bring in sulphur. Drying should be rapid but complete. Kiln scum due to pyrites in ware and coal. Hygroscopic water recondenses in cool parts of kiln and increases drier scum. May contain H_2SO_4 and make more sulphates. H. Guenther has shown that FeS_2 burning forms whitewash. Gerlach does not consider water necessary for this action. Reports six experiments to show that FeS_2 in clay or fuel converts $CaCO_3$ in clay to $CaSO_4$.

1898 FREY, F. E. Efflorescence (whitewashing) of brick. *Clay Worker*, **30**, 105.

Reviews causes. Advises blaming the mortar if possible.

1898 CARSON, J. W. Whitewash and fingermarks. *Clay Worker*, **30**, 120.

Describes common plant troubles.

1898 ANON. Scummed brick. *Brick*, **8**, 56, 187.

Answers to questions on scummed brick.

1898 EDITORIAL. *Brick*, **8**, 165, 222.

Reviews of subject.

1898 EDITORIAL. Witherite. *Brick*, **9**, 32.

Review of its use.

1898 EDITORIAL. Use of $BaCO_3$. *Brick*, **9**, 172.

Advises use of precipitated material.

1899 ANON. Some interesting history of petering of brick walls. *Brick*, **10**, 195.

Goes back to third Napoleon.

1899 SCHALL, S. P. Can discoloration of brick be prevented? *Brick*, **10**, 212.

Describes firing tests with different amounts of $BaCO_3$ as sold by him.

1899 GERLACH, DR. OTTO. On the saline efflorescence of brick. *Brick Builder*, for 1899.

Clearly states the possibility of a reaction between the lime of the brick and the sulphur in the kiln gases to make soluble sulphates.

1899 ANON. Questions and answers on scum. *Brick*, **10**, 252; **11**, 38.

1899 ANON. Description of German plants. *Brick*, **11**, 58.

Cases of efflorescence referred to.

1899 ANON. What makes the white come out on brick walls? *Ohio Valley Manufacturer*. (Reprinted in *Clay Worker*, **32**, 112, and *Clay Record*, **14** [12], 21.)

Review of the question. Advises use of $BaCO_3$.

1899 ANON. Scum or efflorescence. *Clay Record*, **15** [6], 21.

Due to soluble salts in clay, generally sulphates. Reduction at high temperatures best to remove.

1899 ANON. Discoloration of brick work. *Clay Record*, **15** [12], 17.

Review of an article by H. Guenther. Causes given. $BaCO_3$ advised.

1899 ANON. Brickmaking in Yorkshire. *Brick*, **10**, 232.

Face bricks are fired with faces butted so they will not scum. Ends are tarred. In Leeds efflorescence is universal and quality of bricks is very poor.

1899 DISCUSSION, first meeting of the AMERICAN CERAMIC SOCIETY. *Trans. Amer. Ceram. Soc.*, **1**, 104.

The following points were brought out:

1. Kiln scumming occurs more often in the bottom of the setting of a down-draft kiln than in the top.
2. Scummed bricks are harder than adjacent ones in the kiln that are not scummed.
3. Scummed paving brick give good service.
4. Scumming is due to the presence of sulphate of lime.

1901 OGLE, E. M. Unweathered vs. weathered clay. *Trans. Amer. Ceram. Soc.*, **3**, 171.

Drew out Orton on the chemistry of conversion of sulphides to sulphates during weathering.

1901 BROWN, A. E. The drying of ceramic products. *Pottery Gaz.* (Translated in *La Ceramique*, **2** [3], 132.)

Transport of soluble salts to surface the greater the slower the evaporation. Scum can be diminished or prevented by sprinkling the surface of the brick with sand. This makes a dry surface and the salts are deposited inside the brick. This can also be done by causing rapid evaporation at first. Applying a thin coat of flour paste makes the salt deposit on it instead of on the ware.

1902 SEGER AND CRAMER. Prevention of scum. *Tonind. Zeit.*, **26**, 218.

Bricks have been known to scum although the soluble salts in the clay were precipitated by barium addition. This is because soluble salts are made in firing and excess barium salts rendered insoluble as silicates. To prevent this the fired brick should be dipped in barium nitrate or chloride solution. This will precipitate calcium sulphate. Patent applied for.

1902 ANON. Efflorescence on decorated biscuit. *Sprechsaal*, **35**, 1020.

Question: My porcelain biscuit effloresces after it has been decorated and fired. I use only good materials and fire to cone 13–14. How can this be prevented?

Answer: It is hard to answer without more details. Adding a little calcite may help.

1902 ANON. Prevention of discoloration and scum on terra cotta. *Clay Record*, **21** [7], 13.
Long review of known methods written for the practical man.

1903 ORTON. On the rôle played by iron in the firing of clay wares. *Trans. Amer. Ceram. Soc.*, **5**, 377.
Expounds the decomposition of pyrite.

1903 ANON. Efflorescence on bricks. *Zeit. für. öff. Chemie.* (Reprinted in *Tonind. Zeit.*, **27**, 512.)
Describes a serious case of $MgSO_4$ efflorescence during construction of a building. Tests on stock showed more salt in hard burned than in soft burned.

1903 KOCH, J. J. Water-smoking and whitewashing. *Clay Worker*, **40**, 452.
A careful and thorough presentation of the subject.

1903 DE JOANNIS, H. How to overcome the effects of alkali most cheaply in common brick. *Clay Worker*, **39**, 49.
A review of literature and a well-put presentation of the whole subject.

1903 ANON. Brown crusty scum on tile. *Sprechsaal*, **36**, 674.
Question: Has a brown efflorescence on tile. What is cause and how can it be prevented?
Answer: The crust comes from soluble iron salts from pyrite in the tile.

1903 ANON. Efflorescence on glaze. *Sprechsaal*, **36**, 87.
Question: What is the trouble when whiteware shows an efflorescence on the glaze like mildew?
Answer: Too much soda.

1903 ANON. The prevention of scum and discoloration. *Brick*, **18**, 8.
Article extolling the use of $BaCO_3$ and $BaCl_2$.

1904 MÄCKLER, DR. H. The efflorescence of brick work, its cause and prevention. Pamphlet from *Tonind. Zeit.* press.
A thorough presentation in the form of twenty questions and answers. Describes the tests used in Berlin to see if bricks or mortar will effloresce.

1904 MÄCHLER, DR. H. Further investigations of the efflorescence of bricks. *Tonind. Zeit.*, **28**, 436.
Decides that chemical analysis is not an infallible guide to whether a brick will effloresce. $MgSO_4$ and Na_2SO_4 cause efflorescence, K_2SO_4 and $CaSO_4$ do not. Efflorescence may last several years and then disappear. Has made a study of the relation between the amount of soluble salt in a brick, the amount of efflorescence that can be induced, and the size of the pores.

1904 ANON. Perfect color of brick. *Deutsche Toepfer und Ziegler Zeit.* (Reprinted in *Clay Worker*, **42**, 29.)
Soluble salts in raw materials spoil color by crystallizing on the surface, principally sulphates of calcium, magnesium, and the alkalis, also vanadium salts on light colored bricks. A long, well considered article.

1904 ANON. Afflicted with scum. What is the remedy? *Clay Worker*, **42**, 154.
A request for help on scummed paving brick.
Answer: Increase draft on drier or during water-smoking.

1904 ANON. The scum trouble overcome. *Clay Worker*, **42**, 266.
Trouble mentioned in above article has been located and scum stopped.

1904 HIRSCH, H. Clay and salt solutions. *Tonind. Zeit.*, **28,** 231.

Clay in suspension can adsorb salts in solution. This can be prevented by adding aluminum chloride. This is of importance in determining the sulphates and soluble salts in clays.

1904 HIRSCH, H. The "practical" test for amount of $BaCO_3$. *Tonind. Zeit.*, **28,** 491.

While he did not understand the cause of the excessive taking up of barium he found a means of combating it. If 4% $AlCl_3$ be first added, the determination of the amount of $BaCO_3$ necessary to prevent scumming will be faultless.

1904–6 PERKIEWICZ. Protection against efflorescence and the effect of smoke action. *La Ceramique*, **2** [6], 145; [7], 41; [7], 70; [9], 54; [9], 55. (Reprinted in *Tonind. Zeit.*, **28,** 819; **28,** 1604; **29,** 187; **30,** 509.)

A series of articles and patents on a protective coating to be applied to clay wares before firing. The scum is supposed to form in the coat and fall off with it during firing. First flour paste or dextrine proposed. Then a mixture of glue and slip. Then glue and farina and an antiseptic. Machine evolved for applying the coat.

1905 LOVEJOY, ELLIS. Dry-pressed brick. *Trans. Amer. Ceram. Soc.*, **7,** 232.

Described early efforts to combat efflorescence. (See his 1888 article, p. 382.) It was first thought that efflorescence of bricks was due to alkalis but analyses showed that the clay with the least alkali effloresced badly. Then a miner brought a bunch of roots from a clay bed in which the carbon had been replaced by pyrite. Lovejoy began to test for sulphur in clay. He then learned not to weather clay, why crop clay was dangerous, why alkali was not related to scum. They hurried their clay right through to the kiln, roasted out the sulphur before it could oxidize, fired it hard, and guaranteed no efflorescence.

Barium carbonate will not serve on dry-pressed ware. There is not enough water to dissolve it. Barium chloride is far less dangerous than in other processes on this account. The stiff mud process meets its trouble in the drier and to a greater degree than the dry press. Solution takes time. Quick drying and barium are the only remedies now known. Barium best added with the water in the wet pan or pug mill. There is a "kiln white" or scum which comes on the bricks in the kiln and concerning which we have little knowledge and no solution. The use of wet dirty sulphurous coal and wet ware in the kiln tend toward its formation. It occurs on exposed surfaces. That it is a sulphur compound we are reasonably certain, but that it comes from the clay we are not so sure. It is always worse toward the bottom of the kiln. The only remedy is clean dry coal.

1905 GRANGER, A. "La Ceramique Industrielle." Page 31.

"Calcium sulphate is also found in clays, if the body is soft burned, this is only dehydrated and rehydrates in moist air, penetrating the body. This diminishes the solidity. At high temperatures the sulphuric anhydride is volatilized and the base combines with the silica. Calcium sulphate may be formed in firing, if the base is calcareous, from coal rich in pyrite. It produces then the accidents which we will enumerate."

Ibid., Page 207.

"Soft coal used for firing ceramic products is a long flame coal. It should be as far as possible free from pyrite. A sulphurous coal gives in burning sulphur compounds whose presence is objectionable in certain cases."

1905 MÄCHLER, DR. H. Further investigations. *Tonind. Zeit.*, **29,** 437.

Experiments on adding known varying amounts of salts to clays and making bricks. Pore space varied. Results rather indefinite.

1905 ANON. Black efflorescence on doll's heads. *Sprechsaal*, **38**, 1516.
Question: Dolls' heads show sometimes a black efflorescence after glost firing.
Answer: Bisque fire should be hotter.

1906 ANON. *Brick*, **25**, 166.
Account of a suit over cleaning the scum from a brick building.

1906 SMITH, S. Efflorescence on brickwork. *Brick and Pottery Trades Jour.*, **13**, 110. (Reprinted in *British Clayworker, Suppl.*, **14**, 95.)
Review of the subject.

1906 FRANCHE, G. Saline efflorescence on bricks. *La Ceramique*, **9**, 105.
$CaSO_4$ blamed for all the trouble. Discusses relative advantages and costs of (1) addition of $BaCO_3$, (2) coating with flour paste and (3) removal of the diseased surface by a method not described.

1906 KLEIBER, J. Iron pyrite in clay and coal and its damaging effect on the ware. *Tonind. Zeit.*, **30**, 754.
Describes decomposition of pyrite with heat and evolution of H_2SO_4 and formation of low melting iron silicate. Recondensation of sulphuric acid in the ring furnace. Formation of calcium sulphate from a limey clay, formation of scum, change of color.

1906 SEGER AND CRAMER. Several causes for efflorescence on brickwork. *Tonind. Zeit.*, **30**, 1752.
Some rooms in a building had scummed, others had not. Bricks, mortar and water tested all right. The rooms had been dried by a fire burning high sulphur coal and the sulphur had attacked the walls.

1906 ANON. Formation of sulphates in bricks and the cause. *Tonind. Zeit.*, **30**, 2014.
Absorption of sulphate from kiln smoke may be by alkalis and magnesia as well as lime. The alkaline sulphates are easily decomposed, magnesium sulphate less easily. If lime is present it takes the sulphate from the others. Calcium sulphate is decomposed only at high temperatures. Therefore hard-fired ware may contain more sulphate than soft-fired.

1906 LOVEJOY, ELLIS. The use of barium compounds in preventing scums. *Trans. Amer. Ceram. Soc.*, **8**, 255 (1906). (Reprinted in *Clay Worker*, **49**, 668 (1908). *Tonind. Zeit.*, **32**, 1354 (1908).)
Calcium sulphate the chief source of trouble. Discussion confined to it. Seger gives solubility of one part in 386 to 451 parts of water depending on temperature. Scums classified as "wall," "kiln," and "drier." Last only discussed. Generally calcium sulphate. By calculations of amounts dissolved he shows why the little water in dry-pressed ware is less apt to cause scumming than the four times as much in stiff mud bricks. The better circulation of water there is, the better $BaCO_3$ will precipitate $CaSO_4$.
$BaCl_2$ will precipitate $CaSO_4$ but leaves a soluble $CaCl_2$ and excess $BaCl_2$ is soluble. An insufficient amount might help with $BaCO_3$ as well.
Barium acid carbonate suggested, half as soluble as $CaSO_4$.
Barium hydrate would be better, very soluble but unstable. Carbonate could be partly converted and used at once. Excess hydrate would become carbonate.

1906 JONES, J. C. Efflorescence on brick. *Univ. of Ill. Bull.*, **4**. (Reprinted in *Trans. Amer. Ceram. Soc.*, **8**, 369. Advance notice, *Clay Record*, **28** [12], 30. Reprinted **31** [4], 24 (1907).)
Gives history and classification. He made trials of 0.5% each of $CaSO_4$, $MgSO_4$,

$Al_2(SO_4)_3$, $CaCO_3$, Na_2CO_3, NaCl and fired oxidizing. Sulphates scummed much the worst. Gives a very good review of the knowledge to date. Studied and explained a number of typical cases of wall scumming and gives methods of prevention. Gives a bibliography.

1906 ANON. Scum prevention. *Brick and Pottery Trades Jour.*, **14,** 37.
Question: Should I change from $BaCO_3$ to $BaCl_2$?
Answer: No.

1906 ANON. A simple scum preventive. *Brick and Pottery Trades Jour.*, **14,** 75.
Cover articles with tar, oil or starch paste.

1906 ANON. *Brick and Pottery Trades Jour.*, **14,** 147.
Question: Is there anything better than witherite?
Answer: Precipitated barium carbonate.

1906 ANON. Anti-scum paste. *Brick and Pottery Trades Jour.*, **14,** 251.
Question: Formula?
Answer: Starch and glue boiled.

1906 ANON. Efflorescence in the muffle kiln. *Sprechsaal,* **39,** 1336.
Question: Blue overlaid on a white matt glaze changes to black and some white spots show. Black points appear at some places.
Answer: Due to reduction.

1906–7 MELLOR, J. W. The determination of the amount of soluble salts in clays. *Trans. Ceram. Soc.* (Eng.), **6,** 54.
"Scumming is due to soluble salts."

1906–7 MELLOR, J. W. The sulphuring and feathering of glazes. *Trans. Ceramic Soc.* (Eng.), **6,** 71.
Describes the action of SO_2 from coal on glaze to form sulphate crystals.

1907 ANON. Efflorescence on sand-lime brick. *Tonind. Zeit.*, **36,** p. 1907.
The trouble was traced to ashes and cinders dumped in storage yards.

1907 LEDUC, E. The efflorescence of brick. *Rev. Mat. Cons. Trav. Pub.* (Translated in *Brick*, **26,** 300.)
A long article telling the story from the beginning and giving the German methods of testing to determine the right amount of $BaCO_3$. Tests the relative value of barium chloride, aluminate and carbonate as a preventive. Diagrams of testing apparatus.

1907 LOVEJOY, ELLIS. Scumming and efflorescence. Pamphlet printed by F. J. Heer, Columbus, Ohio.
This 60-page pamphlet attacks the problem in a business-like way and coördinates all the scattered information on the subject. Troubles from all possible sources are classified and distinguished from each other and the proper remedies for each are indicated.

1907 FRANCHE, M. Process to suppress efflorescence and spots from ceramic products. *La Ceramique,* **10,** 58.
A mechanical process as follows:
1. A sand blasting of the fired ware.
2. A material and arrangements appropriate. Gives description of sand blasting arrangements.

1907 ZSCHOKKE, B. On the action of different mortars on the efflorescence of masonry. *Eidgenossen Materialsprüfungsanstalt in Zurich*, No. 11, p. 217. (Translated in *La Ceramique*, **10**, 93.)

A long historical descriptive article ending with some tests of actual salts made up in bricks.

1907 COWAN, R. G. Spitting out—a phenomenon of the decorating kiln. *Trans. Amer. Ceram. Soc.*, **9**, 493.

Accounts for this phenomenon as due to the presence of sulphur and reducing gases.

1907 BINNS, C. F. Sulphur and sulphates. *Clay Worker*, **47**, 76.

A very carefully prepared article, written in simple terms, yet covering the cycle of sulphur in clay in its various forms most thoroughly. One of the masterpieces of the subject.

1907 ANON. Efflorescence in the muffle kiln. *Sprechsaal*, **40**, 423.

Question: Painted porcelain shows an efflorescence on the painting which does not appear when the bisque is burned very hard.

Answer: Ware too porous.

1907 ANON. Efflorescence in the muffle on flesh color. *Sprechsaal*, **40**, 633.

Question: How does one prevent efflorescence in the muffle, especially on flesh color?

Answer: Organic bodies are not entirely burnt out and carbon particles remain, especially if base is porous. This causes reduction. Fire longer.

1907 ANON. Efflorescence on glaze. *Sprechsaal*, **40**, 646.

Question: Porcelain glaze comes out of the bisque kiln all right (cone 13–14), but small black points come out in the muffle. Composition of glaze given.

Answer: There may be several causes. Looks like too much scrap in the glaze.

1907 ANON. Scum. *Brick and Pottery Trades Jour.*, **15**, 17.

Caused by SO_3 from coal on condensed water on ware. Heat to 300°F in clean air. Use $BaCO_3$ or coat with paste.

1907 ANON. *Brick and Pottery Trades Jour.*, **15**, 300.

Question: Is there any way to tell if a brick will effloresce?

Answer: Set it over a dish on wires and pour a gallon water through the brick. Evaporate the water. If the residue is great the brick will scum.

1907 ANON. Discolored bricks. *Brick and Pottery Trades Jour.*, **15**, 557.

Question: Buff bricks have developed brown spots or even fur on standing. Why?

Answer: You have run into a higher iron clay in your bank. Weather it.

1907 AN EXPERT. Some defects and their causes. *Brick and Pottery Trades Jour.*, **15**, 16.

Review of subject.

1908 ZSCHOKKE, B. On the effect of various binding materials on the efflorescence of brickwork. *Tonind. Zeit.*, **32**, 380.

Takes exception to Mächler's work. Thinks soluble salts may well come from the mortar or be created or destroyed in firing. Tested eleven binders and found that after setting they were all full of soluble salts. Beside a new building he put a pile of the same bricks loose. After two years the walls were effloresced, the bricks were not.

1908 ANON. What is the remedy for whitewash on shale brick? *Clay Worker*, **49**, 809.

An appeal for help.

1908 LACOUR, C. F. Answer to above. *Clay Worker*, **50**, 50.
Brick must be set dry in kiln.

1908 DRAKEBUSCH, W. Efflorescence on lime sandstones. *Tonind. Zeit.*, **32**, 614.
Refers to Mächler and has much the same problem, including the presence of vanadium.

1909 LOVEJOY, ELLIS. Discolorations on bricks. *Brick*, **30**, 97. (Translated in *La Ceramique*, **12**, 101.)
The whole history of scumming and efflorescence gone over, classified, and each class treated separately. Ends with a list of references. One of the masterpieces of the subject.

1909 ANON. Scum preventives. *British Clay Worker*. (Reprinted in *Brick*, **31**, 334.)
Barium chloride has been patented in Germany as a preventive, but has been tried and given up many times. Barium carbonate is satisfactory.

1909 MILLAR, J. C. How to ged rid of limestone scum from brick. *Brick*, **31**, 335.
An address.

1909 ANON. Cleaning of brick fronts. *Clay Record*, **34** [3], 31.
Sand blast not advised, nor steel wire brush. One part hydrochloric acid to twelve water best. It may be preceded by soap and water.

1909 HENSCHKE AND NIEMER. Method to prevent the efflorescence of whiteware. German Pat. 208,478. (*Sprechsaal*, **42**, 437.)
Pour an excess of barium chloride solution over the ware and steam it.

1909 ANON. Scum. *Thonwaaren Fab.*, **35**, 105.
Ascribes scum to fire gases.

1909 SEARLE, A. B. Scummed or whitened bricks. *The Builders Journal*. (Reprinted in *Brick and Pottery Trades Jour.*, **17** [2], 66.)
In a certain English district all brick had a thin glazed scum. A new type of kiln was built there which produced unscummed bricks. Architects rejected these as underfired. It was found that the general opinion of architects was that bricks with glazed scum were harder.

1909 ANON. White bars on bricks. *Brick and Pottery Trades Jour.*, **17** [9], 421.
Question: How to avoid white stripes or bars on bricks as on samples sent.
Answer: Bars are drier scum caused by drying ware in kiln gases.

1909 ANON. White deposit on bricks. *Brick and Pottery Trades Jour.*, **17** [12], 566.
Question: Wants to prevent kiln scum. Barium carbonate too costly and only partially successful.
Answer: Reduction suggested just before finishing.

1910 ANON. Barium compounds to prevent scumming by sulphates. *Keram. Rund.*, **18**, 241.
Barium chloride as well as carbonate can be used. Chloride works fast but excess will form scum. Carbonate will not. Therefore take three quarters enough chloride to precipitate the sulphates and finish with an excess of carbonate.

1910 N. B. M. A. CONVENTION. What is the best and cheapest method of eliminating whitewash from dry press brick? *Clay Worker*, **53**, 250.
Purdy advises $BaCO_3$. Cement often to blame.

1910 ANON. How to prevent discoloration of brick. *Brick*, **32**, 232.
Question and answer.

1910 ASHLEY, H. E. The technical control of the colloid matter in clays. *Trans. Amer. Ceram. Soc.*, **12**, 768.
Explains the reactions of barium carbonate with gels as well as with sulphates. This is why the "practical" test for the barium carbonate requirement of a clay is liable to lead to waste.

1910–1911 GREAVES-WALKER, A. F. Efflorescence on brick work. *Indus. and Eng. Chem.*, Sept. 1910. (Reprinted in *Brick and Clay Record*, **38**, 365 (1911).) *Brick Builder*, Jan. 1911, p. 86; *La Ceramique*, **14**, 173 (1911); *British Clayworker, Suppl.*, **19**, 86 (1911).)
Deals with the subject under the following heads: (*a*) composition of efflorescence, (*b*) causes, (*c*) methods of overcoming, (*d*) treating the clay, (*e*) treating the water, (*f*) correct drying. One of the leading articles on the subject.

1911 CAMPREDON, M. A new cause of scummed (effloresced) bricks. *British Clayworker*, **20**, 10. (Reprinted in *Clay Worker*, **55**, 745.)
He has found an efflorescence of practically pure sodium carbonate. Traced to the source of water for mortar and dipping bricks before laying.

1911 PERKIEWICZ, M. Protection to prevent the efflorescence of bricks. *La Ceramique*, **14**, 202.
Now uses resin as his base for a coating, or glue or other agglutinant mixed with one or several of a wide range of salts.

1911 HOFFMAN, H. O. AND MOSTOWITSCH, W. Reduction of calcium sulphate by carbon monoxide and carbon and oxidation of calcium sulphide. *Sprechsaal*, **44**, 235.
Reduction without loss of sulphur begins between 680° and 700°. Most rapid at 750° to 850°, complete at 900°. Decomposition in pure dry air begins at 1200°. Calcium sulphide heated in an oxidizing atmosphere becomes 73% sulphate, 27% oxide.

1911 ANON. Greasy scum on whiteware. *Sprechsaal*, **44**, 467.
Question: Special pieces like dish covers are poured instead of pressed. On these pieces we have a greasy scum.
Answer: The slip may be poured into the dried mold too rapidly and air trapped.

1911 ANON. Efflorescence on bricks. *Baumaterielmarkt*, No. **4** (1911). (Reprinted in *Tonind. Zeit.*, **35**, 208.)
Efflorescence appeared on a wall. It was traced back to a setter using ashes instead of sand to separate bricks in a ring furnace.

1911 ANON. Scum on firebricks. *Baumaterielmarkt*, No. **24** (1911). (Abstract in *Tonind. Zeit.*, **35**, 928.)
Descriptive article.

1911 ANON. *Der Thonwaren Fabrikant.*, No. **14** (1911). *Tonind. Zeit.*, **35**, 1070.
Tells the story of efflorescence.

1911 ANON. *Baumaterielmarkt*, No. **48** (1911). (*Tonind. Zeit.*, **35**, 1789.)
Reviews the subject and gives precautions to take.

1911 ANON. Vanadium scum. *Tonind. Zeit.*, **35**, 1045.
Question: A yellow green scum comes out on a yellow whiteware soon after leaving the kiln.
Answer: Heat hotter and reduce. Heat above cone 010

1912 BINNS, C. F. Discoloration on brick. *Brick and Clay Record*, **40**, 186, 415. (Reprinted in *Brick and Pottery Trades Jour.*, **20**, 227, 413.)
A thorough, concise explanation from a chemical point of view of the causes of scumming due to the clay, the water and the kiln gases. Advises the use of barium carbonate. Gives methods of testing water and clay that can be used at any brick plant.

1912 VOIGT, A. More light on efflorescence. *Brick and Clay Rec.*, **40**, 187.
Discusses recent communications.

1912 ANON. Sensible solution of world wide problem. *Brick and Clay Rec.*, **40**, 47.
Discusses scumming and efflorescence. Writer gets rid of it by raising the heat slowly.

1912 ANON. The prevention of scum. *Brick and Clay Rec.*, **40**, 59.
Advocates use of precipitated barium carbonate.

1912 ANON. Scum on best bricks. *Brick and Pottery Trades Jour.*, **20**, 111.
Question: Has scum and wants to avoid it.
Answer: Due either to salt in clay or to incomplete drying.

1912 ANON. Scummed burnovers. *Brick and Pottery Trades Jour.*, **20**, 563.
Question: Underfired bricks reset are generally spoiled with scum. Can this be prevented?
Answer: Dip in gruel before resetting or wrap in brown paper.

1912 ANON. Salty deposits on brick work. *Revue Scientifique.* (Reprinted in *Canadian Clay Worker*, Sept., 1912, p. 21.)
Review.

1912 PERKIEWICZ, M. How to combat scum and efflorescence. *Tonind. Zeit.*, **36**, 577.
Advises coating with bakelite.

1912 SEGER AND CRAMER. Efflorescence on brickwork. *Tonind. Zeit.*, **36**, 1149.
Describes experiments on soaking ware in solutions of various salts and mixtures and then testing for efflorescence. Conclusions point to hydrochloric (muriatic) acid as a good cleaner for efflorescence.

1912 ANON. To prevent efflorescence. *Ziegel und Bau-Industrie.* (Reprinted in *Tonind. Zeit.*, **36**, 1404.)
Advises barium carbonate to precipitate sulphates and ammonium oxalate for excess lime.

1912 ANON. Efflorescence on sand lime bricks. *Tonind. Zeit.*, **36**, 1907.
Bricks were stacked on ashes and absorbed soluble salts which later effloresced.

1913 BINNS, C. F. Efflorescence and how to stop it. *Brick and Clay Rec.*, **43**, 1017.
Goes carefully and thoroughly all over the subject. Does not advise barium chloride but recommends carbonate. Gives very simple method of testing clays to find how much barium carbonate to use.

1913 ANON. Cures clayworkers' worst trouble. *Brick and Clay Rec.*, **43**, 156.
Advises use of precipitated barium carbonate.

1913 ANON. Wants to prevent scummed brick. *Brick and Clay Rec.*, **43**, 805.
Question: Having scum trouble.
Answer: Read the literature. List given.

1913 GRACE, P. Corrects information on scumming. *Brick and Clay Rec.*, **43,** 909.
Corrects recent discussion. Advises the reading of Lovejoy's pamphlet.

1913 ANON. Efflorescence—here it is again. *Brick and Clay Rec.*, **43,** 1037.
Question: Having trouble with efflorescence.
Answer: Read the literature.

1913 POMMER, O. More cures for efflorescence. *Brick and Clay Rec.*, **43,** 1150.
Had bricks scum that had stood two weeks in the drier. Another plant found that Cramer's remedy of reduction was good but turned red bricks brown.

1913 ANON. Scumming. *Brick and Clay Record,* **43,** 909.
An abstract from Lovejoy's "Scumming and Efflorescence."

1913 HOSHOUR, C. Prevention of whitewash. *Clayworker,* **59,** 402. (Reprinted in *Canadian Clay Worker,* April, 1923, p. 34.)
A long address to the N. B. M. A. Convention. Advises $BaCO_3$.

1913 ANON. Efflorescing salts on brick. *Tonind. Zeit.*, **37,** 1958.
In a case of dispute there were found in some instances 0.4% to 0.5% soluble salts, in others 0.001% to 0.003%. The difference was found in the firing. The bricks low in soluble salts were yellow and hard fired; the others were dark and underfired. The cause of efflorescence is held to be sulphur in coal. Thorough firing is urged as a means of preventing efflorescence.

1913 ANON. Yellow efflorescence on stove tile. *Keramische Rundschau,* **21,** 201.
Due to soluble salts, especially sulphates, which may have entered in any of several ways.

1913 ANON. Efflorescence on porcelain glaze. *Keram. Rund.*, **21,** 169.
May be due to impurities in glaze as gypsum. Try changing materials and coal.

1913 ANON. Produces scum on drying ware. *Brick and Clay Rec.*, **43,** 1152.
Waste flue gases may be used for drying but should first be diluted.

1913 ANON. Efflorescence due to cement coloring. *Tonind. Zeit.*, **37,** 573.
Colorants sometimes contain water soluble salts which cause efflorescence.

1913 A. R. Efflorescing salts. *Tonind. Zeit.*, **37,** 1985.
Describes experiments with mixtures.

1914 ANON. Scum-free water hardening mortar. *Tonind. Zeit.*, **38,** 1507.
A German patent. Contains barium fluoride.

1914 ANON. Efflorescence on red tile. *Keram. Rund.*, **22,** 92.
The trouble is due to soluble sulphates which have entered the ware in some way. Test your sand and grog.

1914 ANON. Efflorescence on stove tile. *Keram. Rund.*, **22,** 235.
Answer: The efflorescence is due to soluble salts which, in a kiln of your kind, can be traced only to the lining.

1914 ANON. Efflorescence and stains on terra cotta. *La Ceramique,* **17,** 186.
A long general review.

1914 ANON. More scum trouble. *Brick and Clay Rec.*, **44,** 90.
Our brick scum on one side and two ends, not on side against rollers of table.
Answer: More probably drier trouble. Mark brick and read Prof. Binns' article. *Brick and Clay Rec.*, **43,** 1017 (1913).

1914 ANON. Has scum trouble. *Brick and Clay Rec.*, **44**, 363.

Brick are a clear clean color before being wet, then effloresce very badly. Have read Prof. Binns' article. Where can I get barium chloride?

Answer: Advises weathering clay, washing if lime is in pebbles, getting an analysis of clay and asking an expert.

1914 BOSS, J. C. Reply to C. F. Binns' article. *Brick and Clay Rec.*, **44**, 263.

Whitewash or efflorescence is brought about in three ways. First, if the moisture is brought to the boiling point before it can escape from the drier. Second, if clean dry bricks are set in a kiln and the moisture comes to a boiling point before it is expelled from the kiln, whitewash is reëstablished. Third, if not properly vitrified, they will immediately effloresce when wet.

1914 BINNS, C. F. Reply to J. C. Boss. *Brick and Clay Rec.*, **44**, 370.

Binns' article was on scumming and had nothing to do with efflorescence. Brick are never at first put into an atmosphere in the drier as hot as boiling water. It is never entirely true that efflorescence is a deposit. Will answer definite questions.

1914 KINNISON, C. S. Ashes and scumming. *Brick and Clay Rec.*, **44**, 588.

Many a case of scumming is due to ashes. Also bricks should never be stacked in ashes.

1914 BUTLER, W. A. Scum—what is it? *Brick and Clay Rec.*, **44**, 592.

Scum is condensed water smoke. Subject explained from this viewpoint.

1914 BINNS, C. F. Scum once more. *Brick and Clay Rec.*, **44**, 1049.

States the facts in regard to scum even more simply and clearly than has already been done.

1914 KNAPP, E. W. Whitewash. *Brick and Clay Rec.*, **44**, 1050.

Gives rule-of-thumb tests to locate trouble and get rid of it.

1914 ANON. *Brick and Clay Rec.*, **44**, 1150.

Advises use of $BaCO_3$.

1914 ANON. Seems to have the old scum trouble. *Brick and Clay Rec.*, **45**, 52.

Question and answer on drier scum.

1914 BENTLEY, M. D. Scum. *Brick and Clay Record*, **45**, 58.

"We know everything about scum except how to be rid of it." Gives good advice on kiln firing.

1915 STALEY, H. F. The use of barium fluoride for the prevention of drier scum on bricks. *Trans. Amer. Ceram. Soc.*, **17**, 200.

Advantages of fluoride over carbonate are:

1. It is less expensive.
2. It is more soluble than $BaCO_3$.
3. The amounts required are the same or less.
4. It has no deleterious effect on the color of the fired ware.
5. An excess does not produce a scum.
6. It promotes vitrification.

(EDITOR'S NOTE: Barium fluoride is now very scarce in commercial quantities. It sells at 18 c. a pound, compared to 5 c. a pound for barium carbonate.)

1915 STALEY, H. F. The effect of salts on the drying behavior of some clays. *Trans. Amer. Ceram. Soc.*, **17**, 697.

While both common salt and soda ash increased the amount of scum found on drying, they caused no scum on fired ware. In one case increasing amounts of these salts

progressively decreased a scum already present. They evidently volatilized or fluxed the scum.

1915 WILLIAMS, A. E. Experiments to overcome scumming and improve the color of bricks. *Trans. Amer. Ceram. Soc.*, **17**, 764.

Tried spraying solutions of ferrous sulphate and ferric chloride on wet and dry green brick. On dry brick there was no effect ever. On wet brick, scumming was diminished or prevented and the ware flashed better. Ferric chloride served better than ferrous sulphate.

1915 EMLEY, W. E. AND YOUNG, S. E. The production, manufacture and use of compounds of barium. *Trans. Amer. Ceram. Soc.*, **17**, 240.

Describes occurrence and manufacture of compounds. Use of chloride and carbonate to prevent efflorescence. Describes "practical" plant control method with chloride. Recommends adding nearly enough chloride, balance carbonate.

1915 Garve, T. W. Notes on German clay working plants. *Trans. Amer. Ceram. Soc.*, **17**, 592.

Describes a plant firing a limey clay with sulphurous brown coal in a ring furnace without advance heating flues. Clay is very fine ground to avoid popping. Reduction is applied for from twenty minutes to two hours to decompose the calcium sulphate on the surface. The characteristic buff lime-iron silicate is formed.

In another plant making roofing tile the clay bar from the augur machine is coated with glue to prevent scumming.

1915 WILLIAMS, A. E. How to prevent efflorescence in finished brickwork. *Brick and Clay Rec.*, **47**, 341.

A thoroughgoing treatise on this subject. Emphasizes the importance of removing the fires and ashes at the end of firing. Mortar should be treated with barium carbonate.

1915 ANON. Removing and preventing efflorescence. *Brick and Clay Rec.*, **47**, 420.

Question about mortar freezing and efflorescence trouble. Answer gives a soap and alum wash to waterproof the wall.

1915 ANON. Removing efflorescence from finished brickwork. *Brick and Clay Rec.*, **47**, 441.

Review of the subject.

1915 ANON. Making clean brickwork. *Brick and Clay Rec.*, **47**, 506.

Wall efflorescence often due to mortar. Describes methods of cleaning and waterproofing.

1915 ANON. Cleaning scummed brickwork. *Brick and Clay Rec.*, **47**, 659.

Williams recommends washing with 10% hydrochloric acid, or 1% soap and then acid.

1915 ANON. Efflorescence on Majolica enamel. *Keram. Runds.*, **23**, 254, 261.

Question: We have occasionally found that our near-majolica ware has an efflorescence after standing a while.

Answer: The enamel is not properly mixed.

1916 WILLIAMS, A. E. Dissociation of calcium sulphate and the removal of drier scum. *Trans. Amer. Ceram. Soc.*, **18**, 271.

Laboratory experiments on reducing gypsum and clay mixtures show that reduction is rapid at 800°C.

Tests for substitutes for barium carbonate showed that barium fluoride and hydroxide and sodium oxalate and fluoride were equally good.

1916 ANON. The effect of mine water on finished ware. *Brick and Clay Rec.*, **48,** 248.
Question: Will water pumped from a coal mine cause scum if used to pug clay?
Answer: It probably will.

1916 ANON. Used wrong acid on brickwork. *Brick and Clay Record*, **48,** 448.
Question: I washed a church with acid to remove scum. I was sold sulphuric instead of muriatic. On drying a white coating developed. Is there any hope?
Answer: Only years of weathering.

1916 ANON. Will weathering clay minimize scumming? *Brick and Clay Rec.*, **48,** 645.
Question: Would weathering help a marl that scums though water-smoked with wood?
Answer: Probably, but it would take a long time.

1916 ANON. Salt glazed brick "whitewash" after exposure. *Brick and Clay Record*, 48, 1042.
Question: Have tried salt glazing bricks which sometimes scum a bit. They turned white 24 hours after leaving the kiln. Can this be prevented?
Answer: Use less salt and higher temperature. Salt is not much good below cone 4.

1917 BINNS, C. F. Efflorescence and how to stop it. *Brick and Clay Rec.*, **50,** 659.
Goes very carefully all over the subject again, clearing up points apparently misunderstood in his article in 1913. (*Brick and Clay Rec.*, **43,** 1017.)

1917 ANON. Is your scum due to these causes? *Brick and Clay Rec.*, **51,** 413.
Methods of avoiding water condensation on ware.

1917 PALLUS, H. AND JAKOB, K. Efflorescences. *Tonind. Zeit.*, **41,** 155, 283, 401.
A brief discussion of these occurrences in bricks. P. states that the best way of destroying the salts is a sharp fire. J. contributes a critical review. P. replies.

1918 ANON. Using barium carbonate to prevent scum. *Brick and Clay Record*, **53,** 54.
Coral Ridge Clay Products Co. adds 28 lbs. of barium carbonate dry per M bricks at the dry pan. Gets better and darker reds.

1918 ANON. *Brick and Clay Rec.*, **53,** 1161.
Question: Want something to add to brick to prevent efflorescence.
Answer: See preceding article.

1920 GATES, M. E. A satisfactory method of using barium hydrate in terra cotta bodies. *Jour. Amer. Ceram. Soc.*, **3,** 313.
Need not use a double portion as with carbonate, therefore cheaper. Shows device to get the barium into solution warm and feed it at a constant rate.

1920 ANON. "Scumming bothers this concern." *Brick and Clay Rec.*, **57,** 64.
Question: Wants to know if waste heat from kilns can be used for water-smoking and not cause scum.
Answer: It is often done and may or may not cause trouble. Fire boxes should be cleaned first.

1920 LOVEJOY, ELLIS. Burning clay wares. Published by T. A. Randall & Co., Indianapolis, Ind. 2nd edition, 1922.
On pages 328 to 332 describes the usual forms of scum and some unusual cases that have come to his attention.

1920 ANON. Scum on brick. *Clay Worker*, **73,** 37.
Question: Has scum trouble and sends two sample bricks.

Answer: One was scummed by sulphur in the die oil, the other apparently by sulphur in the coal.

1921 ANON. Scumming of whiteware and peeling off of glazes. *Sprechsaal*, **54**, 429.
In whiteware there is often a tendency for glaze to peel off especially along the edges due to soluble sulphates. This scum prevents glaze from sticking to body. Barium chloride or carbonate will prevent the scum.

1921 ANON. The use of barium fluoride to prevent scumming. *Sprechsaal*, **54**, 547–8. (*Ceram. Abstracts*, **1** [8], 212.)
Refers to Lovejoy's and Staley's articles and gives their same arguments.

1921 ANON. Eliminating white scum from face brick. *Brick and Clay Rec.*, **59**, 365.
Question and answer.

1922 PARMELEE, C. W. Soluble salts and clay wares. *Jour. Amer. Ceram. Soc.*, **5** [8], 538. (Reprinted in *Brick and Clay Rec.*, **61**, 249, 316.)
Definitions of efflorescence and scum. Description of their occurrence, formation and prevention. Describes a white scum often found in a kiln on opening and which readily disappears. It was chiefly sodium sulphate and chloride. He suggests that it came from the fires and ash after the ware had cooled too low to form a glaze.

1922 HIRSCH, H. Scum on bricks. *Tonind. Zeit.*, **46**, 521.
Discolorations on bricks described and sources traced. Manganese mentioned as an occasional source.

1922 HILL, C. W. Notes of green staining of clay ware. *Bull. Amer. Ceram. Soc.*, **1** [2], 51. (With *Journal* of June, 1922.)
Yellow green staining on ceramic products exposed to weather has usually been ascribed to vanadium. Seger's view has been perpetuated in the literature. Hill found green on ware from clay containing pyrites. Digestion of a sample of stain with acids gave no iron test. Fusion with alkali and solution in acid developed a heavy iron test. Iron apparently combined with alumina or silica. This test has since been repeated with a positive result for iron whenever examples of green staining could be found. The stain is dissolved by oxalic acid or alum and sulphuric acid.
Seger's clays seem to have been different, but Hill is inclined to believe that with Eastern and Central clays the stain is probably due entirely to iron.

1922 ANON. Scum on Belgian bricks. *Tonind. Zeit.*, **46**, 632.
Analysis showed 92–7% magnesium sulphate.

1922 ANON. Cause of black efflorescence. *Sprechsaal*, **55**, 309.
Question: What is the cause of black efflorescence at decorations?
Answer: Reduction.

1922 KALLAUNER, O. AND HRUDA, I. The occurrence of vanadium in ceramic raw materials and ware and its effect upon the fusibility as well as the color and formation of scum on a pure kaolin and a brick clay. *Sprechsaal*, **45**, 333–5, 345–9. (*Ceram. Abstracts*, **2** [3], 57.)
Quantitative results on mixtures fired at different temperatures both oxidizing and reducing with various preventive salts added. Barium and calcium carbonates are good.

1922 ANON. Use of barytes in overcoming scum. *Brick and Clay Rec.*, **60**, 49.
Question: Wants to know how to use barytes in stiff mud plant to overcome scum.
Answer: It may be added at the dry pan. It is better to add only milk of barytes at the pug.

1922 ANON. Use of barytes in controlling scum. *Brick and Clay Rec.*, **60**, 298.
The above repeated.

1922 ANON. Difficulties in scumming. *Brick and Clay Rec.*, **60**, 386.
Question: Have trouble with scumming even with barium carbonate and require 200 hours to burn ware.
Answer: Better have a consultant.

1922 ANON. Scumming efflorescence and whitewash. *Brick and Clay Record*, **60**, 602.
A long thorough description with illustrations and several references. Gives 13 causes and 14 methods of prevention.

1922 ANON. Troubled with intermittent whitewash. *Brick and Clay Rec.*, **60**, 859.
Question and answer.

1922 ANON. Troubled with whitewash. *Brick and Clay Rec.*, **60**, 935.
Question and answer.

1923 BLEININGER, A. V. The effect of acids, alkalis and salts on clay bodies. *Ceramist*, **3** [1], 48.
Discusses soluble salts and their determination. Their accumulation on the surface and particularly the edges of whiteware results in a skin which will not take a glaze. Remedy, barium carbonate. Mention effects on heavy clay wares.

1923 ANON. Scumming on roofing tile. *Tonind. Zeit.*, **47**, 272.
Soluble salts cause scumming which has been prevented with barium carbonate. This is becoming too expensive. The amount has sometimes been reduced by adding fine sand to clay, thus reducing the percentage of soluble salts.

1923 ANON. White scum on brickwork. *Deut. Töp. Zieg. Ztg.*, **54**, 144.
This is not always due to the raw materials. Instances are cited (*a*) stored in unsuitable places at building site, (*b*) impure water or unsuitable materials for mortar, (*c*) insufficient protection from external influences.

1923 BIGOT, F. Stain and efflorescence on ceramic products. *Rev. Mat. Constr. Trav. Pub.*, **166**, 122–213. (*Ceram. Abstracts*, **2** [12], 288.)
Green stain or efflorescence has been noticed on clays heavily charged with mica. A kieselguhr containing manganese did the same on exposure. A stoneware clay with a 2–3% chromite fired to 1200° oxidizing developed green scum. Calcareous white bodies for faience with heavy lead glaze often show the yellow characteristic of lead and chromium. This is not observed in tin opaque glazes. The green is found on clays containing alkalis, large quantities of alkaline earths not preventing its formation.

1923 LOVEJOY, ELLIS. Coloration, discoloration and other burning effects. *Clay Worker*, **79**, 38. (*Ceram. Abstracts*, **2** [5], 96 P.
A long and thorough exposition of the subject.

1923 ANON. Getting rid of scum. *Brick and Clay Rec.*, **63**, 348.
Question: Nature of green stain on light buff face brick.
Answer: Has been ascribed by Seger to vanadium salts or algae. Hill ascribes to iron. See *Jour. Amer. Ceram. Soc.*, June, 1922, p. 51.

1924 JACKSON, F. G. The behavior of calcium compounds in clays. *Jour. Amer. Ceram. Soc.*, **7** [6], 427.
Previous theories on the formation and decomposition of calcium sulphate as kiln scum are confirmed. Quantitative analyses on the effect of definite heat treatments put the subject on a more definite basis.

1924 STRAUMFORD, J. F. How we eliminated scum on sewer pipe. *Brick and Clay Rec.*, **65,** 385.

Scum formed on sewer pipe during glazing due to oil as fuel. Found scum caused by reducing conditions.

1924 ANON. Eliminating scum. *Brick and Clay Rec.*, **65,** 404.

Question: Have just had an entire kiln scum. Have had very little before. We fire with natural gas, water-smoke six days with doors wide open. Clay came from a newly stripped part of bank.

Answer: Sounds like sulphate scum caused by a partially soluble salt. Try barium carbonate.

ACTIVITIES OF THE SOCIETY

NEW MEMBERS RECEIVED FROM JUNE 15 TO JULY 15

PERSONAL

Jean Boyau, % International General Electric Co., Schenectady, N. Y.

John Burgess, Jr., % Gordon Kaolin Co., Gordon, Ga. Superintendent.

A. DeGallaix, 359—1st St., Niagara Falls, N. Y. Ceramic Engineer, Carborundum Company.

Clyde Denlinger, 205 Norwood Ave., Buffalo, N. Y. Superintendent, Steel Division, Bethlehem Steel Co., Lackawanna, N. Y.

C. Arnold Dutton, 1262 Ontario St., Cleveland, Ohio. District Sales Representative, Carborundum Company.

W. H. Funk, Harbison-Walker Refractories Co., Pittsburgh, Pa.

Samuel V. Jolliffe, Box 1672, R. R. No. 2, Glendale, Calif. Superintendent, Terra Cotta Department, Los Angeles Pressed Brick Co.

Donald K. Macleod, % Gladding, McBean & Co., Glendale, Calif. Superintendent, Tile Department.

Herbert P. Margerum, % Golding Sons' Company, Trenton, N. J. President.

A. G. Mason, Lisbon, Ohio. Manager, Lisbon Factory of the R. Thomas & Sons Co.

Fred W. Miller, 812 Kenmore Road, Overbrook, Philadelphia, Pa. The Carborundum Company, Perth Amboy, N. J.

Cullen E. Parmelee, Crystal, Mo. Pittsburgh Plate Glass Co.

John A. Paulsen, % Thos. Moulding Brick Co., 133 W. Washington St., Chicago, Ill. Refractories Sales Manager.

J. A. Rumer, 54 N. Parkside Ave., Apt. 1, Chicago, Ill. Chicago Representative of The Ferro Enamel Supply Co.

R. L. Shugg, General Motors Bldg., Detroit, Mich. Assistant District Manager, American Rolling Mill Co.

William H. Vaughan, Georgia School of Technology, Atlanta, Ga.

CORPORATION

Hydraulic-Press Brick Co., 705 Olive St., St. Louis, Mo. George F. Baker, Secretary and Treasurer.

Membership Workers' Record

	Personal	Corporation
Charles F. Geiger	4	
Roy A. Horning		1
C. R. Minton	1	
Cullen W. Parmelee	1	
P. H. Walker	1	
R. A. Weaver	1	
Office	8	
	16	1

PRESENT ADDRESSES UNKNOWN

NOTE: Kindly notify the Secretary of the SOCIETY if you know the correct address of any of the members listed herewith.

All-In-One Plumbing Fixture Corp., 231 Ochsner Bldg., Sacramento, Calif.
William Birner, Box 139, R. R. No. 1, East San Gabriel, Calif.
G. V. Baker, Pennsylvania Feldspar Co., Barnard, N. Y.
Leo T. Butman, F. R. Muller & Co., Waukegan, Ill.
J. P. Callaghan, % Teaque Hotel, Montgomery, Ala.
Edna P. Carson, Schenley High School, Pittsburgh, Pa.
T. M. Caven, 564 W. 173rd St., New York City.
Frank J. Connors, Y. M. C. A., Room 14, Winsted, Conn.
August F. Danes, Laclede-Christy Clay Products Co., St. Louis, Mo.
Charles S. Dolley, Keramoid Mfg. Co., Fort Madison, Iowa.
S. P. Edson, Bryantville, Mass.
P. P. Francais, 1329—7th St., Lorain, Ohio.
M. S. Gifford, Lake Bluff, Ill.
A. H. Goodman, Box 915, Pittsburgh, Pa.
John L. Greenwood, Lehigh Sewer Pipe & Tile Co., Lehigh, Iowa.
C. Knox Harding, 6318 Stony Island Ave., Chicago, Ill.
Kenneth E. Holley, Alfred, N. Y.
Isaac Kahn, 2428 Reading Road, Cincinnati, Ohio.
G. S. Kennelley, 3265 Philadelphia W., Detroit, Mich.
J. M. Knote, J. H. Gautier & Co., Green & Essex Sts., Jersey City, N. J.
Roy Lacy, 634 S. St. Andrews Place, Los Angeles, Calif.
Arthur T. Leahy, 5490 Ellis Ave., Chicago, Ill.
William W. Lemmax, Box 59, Taylor, Wash.
George W. Lester, 2176 McClellan Ave., Detroit, Mich.
F. G. Lord, Pennsylvania Pulverizing Co., 341—4th Ave., Pittsburgh, Pa.
A. T. Meldram, Strathcona Potteries, 99 St. James St., Montreal, Can.
C. F. Miller, University of Washington, Seattle, Wash.
F. H. Nies, Hamilton Ave. & Summit St., Brooklyn, N. Y.
F. W. Owens, 3507 E. Baltimore St., Baltimore, Md.
Walter A. Preische, Alfred, N. Y.
H. M. Pulsifer, Manhattan Bldg., Chicago, Ill.
Gordon W. Reed, 407 S. Dearborn St., Chicago, Ill.
A. E. Saunders, 48 Albemarle Ave., Toronto, Ont., Can.
A. Lincoln Scott, Auditorium Tower, Chicago, Ill.
Lee Showers, Pittsburgh Plate Glass Co., Pittsburgh, Pa.
Olin F. Shults, Alfred, N. Y.
George Sirovy, 1486 Perry St., Des Plaines, Ill.
Clarence A. Stimpson, Chicago Pneumatic Tool Co., Century Bldg., Chicago, Ill.
Charles H. Stone, Jr., 1210 Oak St., Jacksonville, Fla.
Evelyn Tennyson, Alfred, N. Y.
Erwin F. Theobald, General Delivery, Bessemer, Pa.
Boris Trifonoff, 631 Putnam Ave., Zanesville, Ohio.
Mrs. David Vanderkooi, 733 Michigan Ave., Portland, Ore.
Bernard Vane, Hopewell, Va.
John H. Voorhies, Alfred, N. Y.
Frank A. Weidman, 38 S. Dearborn St., Chicago, Ill.
G. N. White, 7 Victoria Ave., Worcester, England.
Heinrich Willmer, Cologne Nippes, Germany.

PERSONAL NOTES

Robert J. Anderson, Metallurgical Engineer, has moved his consulting office from Boston, Mass., to Pittsburgh, Pa., and is living at 221 Amber St., E. E., Pittsburgh.

F. S. Crumley, President of the Indiana Sanitary Pottery Co., has moved from Chicago to 407 Johnson St., Hammond, Ind.

Albert C. Gerber, who has been employed as Ceramic Engineer for the J. L. Mott Co., of Trenton, N. J., has recently taken a similar position with the General Ceramics Co., of Metuchen, N. J.

Robert E. Gould, who received his degree in Ceramic Engineering in June, 1925 at Ohio State University, is employed by the R. Thomas & Sons Co., Lisbon, Ohio.

Richard D. Hatton, formerly Vice-President and General Manager of the Lacledе-Christy Clay Products Co., now holds a similar office with the Los Angeles Pressed Brick Co., Los Angeles, Calif.

F. A. Kirkpatrick has moved from Burlingame, Calif., to Unionville, Mich.

A. R. Mallon has moved from McKees Rocks, Pa., to 1216 Greenfield Ave., Canton, Ohio.

Joseph K. Moore of New York City writes that his present address is 701 N. Michigan Ave., Chicago, Ill.

Howard W. Pigott has moved from Philadelphia, Pa., to 416 Addison Road, Riverside, Ill.

F. W. Runge, formerly connected with The Ferro Enameling Co., Cleveland, Ohio, has accepted a position with the Andes Range & Furnace Corp., of Geneva, N. Y.

Leonard Sheerar has taken a position with the Dover Fire Brick Co., Dover, Ohio. Mr. Sheerar received his degree of Master of Science in Ceramic Engineering at Ohio State University, June 1925.

George R. Snyder, Metallurgist for Harbison-Walker Refractories Co., has been transferred from the Pittsburgh office to the Buffalo office of that Company.

CALIFORNIA LOCAL SECTION

A meeting of the California Local Section was held in Los Angeles, June 29. There were forty-seven in attendance. The dinner was followed by a very interesting program which consisted of:

"The Machinery Arrangement for the Clay and Grog Preparation in the Manufacture of Glass Pots and Tank Blocks," by T. W. Garve.

"Flint Glass for Prescription Bottles," by W. H. Test.

"Window Glass Manufacture in Southern California," by LeRoy Dixon.

"Some Orange County Clays," by Ray Boggs.

W. H. Sheppard of the Los Angeles Chamber of Commerce gave an inspiring talk on ceramic education in California. A resolution was adopted to further the movement to establish a ceramic course at the University of California, Southern branch. F. B. Ortman was appointed to head the committee to coöperate with the Chamber of Commerce and the State Education authorities.

HEAVY CLAY PRODUCTS DIVISION

Your Committee on Research would be interested to know what researches the members of the Division are contemplating or carrying on at present. We would also be glad to receive suggestions. If you have any question that is troubling you and that can be settled by investigation, let us know about it.

If you pick up any facts of general interest, send them in. Here is an example that your chairman recently found at a sewer pipe plant. The kiln was 32 feet diameter and the charge weighed 43.5 tons. Each shovelful of coal weighed 11.1 pounds. There were 9 fireboxes. Therefore, when the fireman went around and put, for example, three shovelfuls on each fire, he had put on 300 pounds of coal. During the first 50 hours of firing, every 100 pounds of coal raised the kiln temperature 10°F. Eight hundred degrees F was attained with 8000 pounds of coal. Before 900°F was reached the fires had been cleaned and a total of 13,000 pounds of coal had been used. One hundred degrees F was rapidly gained after this and the ratio still held up to 1400°F. One thousand one hundred degrees F cost 14,000 pounds, 1200° cost 15,000 pounds, 1300° cost 16,000 pounds, and 1400° cost 17,000 pounds. After that the coal consumption increased more rapidly than the temperature. Temperatures were taken seven feet in through the wicket. Of course a charge of 12-inch sewer pipe does not weigh much compared with brick, and therefore heats with less coal. Can anyone else send in some figures like this?

F. G. JACKSON, Chairman, Comm. on Research.

SUMMER MEETING IN CANADA

Forty-six members of the AMERICAN CERAMIC SOCIETY attended the recent Summer Meeting of the SOCIETY held in Canada July 4–11. A total registration of 165 was made. The papers presented at the technical session held in Toronto on July 9 are presented in this issue of the *Bulletin*.

NOTES AND NEWS

G. A. BOLE MADE SUPERVISING CERAMIST OF U. S. BUREAU OF MINES

G. A. Bole is designated as Supervising Ceramist of the Bureau of Mines and as such will have technical supervision of all ceramic investigations carried on by the Bureau, both at the Columbus Station and at the other experiment or field stations, acting through the respective station superintendents in the usual manner. Mr. Bole will also continue in his position as Superintendent of the Columbus Station.—

D. A. LYON, Acting Director, Dept. of Commerce, Bureau of Mines.

GLASS TECHNOLOGY IN THE UNIVERSITY OF PITTSBURGH

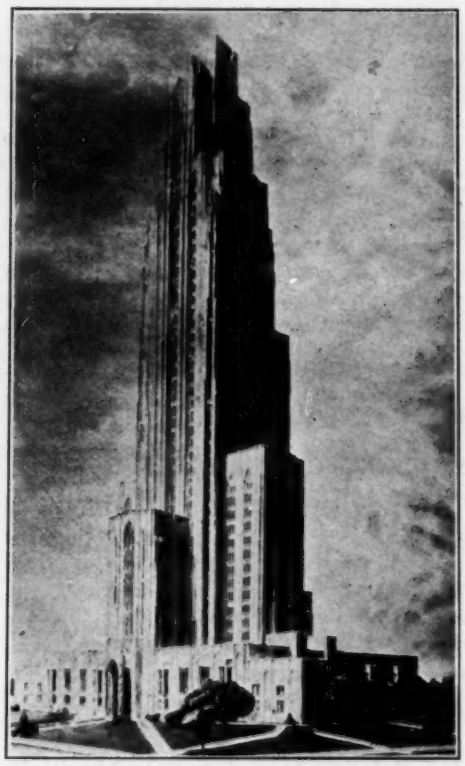
BY ALEXANDER SILVERMAN

When the writer was called into a glass factory as chemist in 1902, just after graduating from college, there was little in America that might be honored with the title "Glass Technology." Chemists in the industry could be counted on the fingers of one hand. Today we find more chemists in the laboratories of a single manufacturer than the entire industry employed only twenty years ago.

In the University of Pittsburgh the study of glass has been confined to a lecture course on the subject; to graduate research by candidates for masters' and doctors' degrees; to investigations, in the field of pure research, or in a consulting capacity, by professors; and to the industrial researches under the fellowship system in the Mellon Institute of Industrial Research. The lecture course in glass technology has rarely

been available for any but graduate students because of the importance of physical chemistry, which students pursue during their senior year.

While it is not likely that students will be able to enter properly upon the study of the science of glass making until they have had training in inorganic, analytical, and physical chemistry, and in the fields of physics and mathematics, one might perhaps have the freshman make silicate and borate melts during the study of silicon and boron and later, when he studies the alkali and alkaline-earth metals, let him prepare a few simple glasses. Analytical chemistry might include the examination of raw materials and glasses, physical laboratory practice can cover the making of physical measurements on glass, and physical chemistry might include a study of eutectics and equilibria as well as the influence of temperature on chemical reactions and physical properties. Whether a four-year undergraduate course will be established to train glass technologists is still uncertain, but that a beginning will be made in training men for this important industrial field is assured.



Men on the faculty of the University, and in the Mellon Institute, have made such progress in glass investigation during the past score of years that attention is focused on the University, with the expectancy of further development. Pittsburgh is one of the most important glass centers in the world, if not the most important. The industry began in this district in 1797. Pittsburgh today manufactures more than one-half of the window glass of the United States and one-third of the plate glass and pressed and blown ware of the country. Its bottle plants turn out one-eighth of all glass containers used.

The University of Pittsburgh is glad to announce a gift of fifty thousand dollars for the establishment of the first "Laboratory of Glass Technology" in an American institution of higher learning. This will be a part of the Chemistry Department and will be located in the new "Cathedral of Learning," the fifty-two story building on which the University plans to begin building operations in the Fall, completing the structure in approximately three years. The contribution comes from Isaac W. Frank, in memory of his father, William Frank, who was one of Pittsburgh's pioneers in the glass field. It is expected that an additional amount will follow the original gift.

With this prospect, the University of Pittsburgh hopes to fill the long-felt need for the training of technical men for the glass industry.

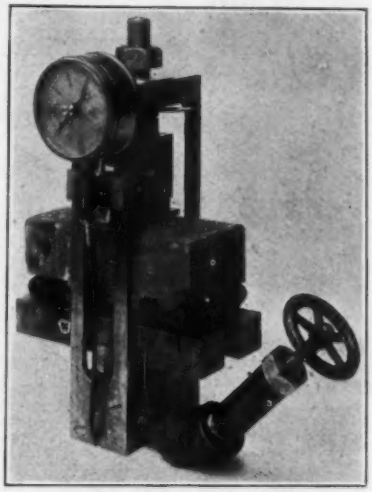
DEPARTMENT OF CHEMISTRY
UNIVERSITY OF PITTSBURGH

BUREAU OF STANDARDS NOTES

Portable Brick Tester

1. This machine was designed for an oil pressure of 2000 pounds per square inch or a total compressive load of 4000 pounds. It consists essentially of the equalizer apparatus for transverse tests of brick described in Bureau of Standards Technologic Paper, No. 251 and a hydraulic jack which applies the load. It is comparatively light in weight (about 35 pounds), simple in operation and accurate in determining the breaking load.

2. By its use, it is hoped that delays incident to sending samples of brick to a testing laboratory can largely be avoided and that the inspector on the job can determine whether the brick have the required strength. This will tend to eliminate controversy between the contractor and inspector, and also between the manufacturer and the contractor.

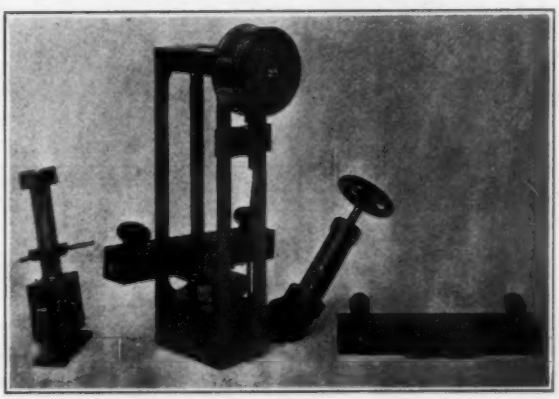


3. These machines are made by the Morehouse Machine Company, 233 West Market Street, York, Pa.

Technical News Bulletin, No. 98, gives the following description of the tester:

"A portable machine for testing brick in cross bend has been designed by A. H. Stang, of the engineering mechanics section of the Bureau, and construction is practically completed. The machine will weigh about 40 pounds, is hydraulically operated, 16 inches high, 6 inches wide and 12 inches long.

"On account of the proposed change in the A.S.T.M. specifications, for brick testing, which will probably eliminate all physical tests except the cross-bend test,

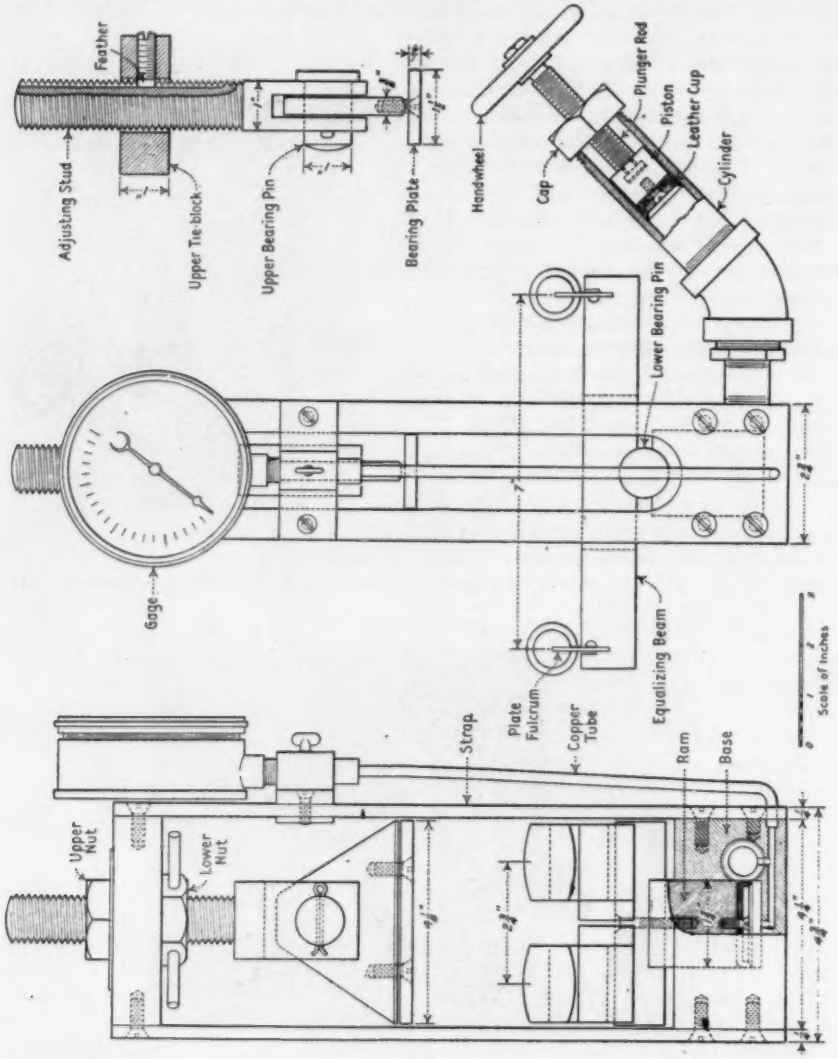


the need for such a machine is evident. With this machine an inspector can test brick on the job and will not need to send specimens to a distant testing laboratory. Delays can thus be avoided and a real indication given of the quality of the brick."

Architectural Terra Cotta Investigations

The National Terra Cotta Society for a number of years has been supporting a research associate at the Bureau with the object of securing and maintaining a quality of architectural terra cotta which will give the best performance of this ware in buildings

The physical properties of terra cotta have been determined, including compressive strength, transverse strength, tensile strength, resistance to freezing and the coefficient



of expansion. The tensile strength, as compared with building stone of like absorption, was found to be high. Investigations of the expansions of the glaze, body and underslips have also been undertaken. The coefficients of expansion of 20 samples of each on these materials have been measured by the interferometer method. Crazing of

ORGANIZATION CHART OF THE BUREAU OF STANDARDS

Revised to June 18, 1925

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George K. Burgess, Chairman
Federal Specifications Board
STANDARDIZATION OF SPECIFICATIONS H. F. Harriman
DICTIONARY OF SPECIFICATIONS A. S. McAllister

the glaze in some cases was found to be due to the glaze having a greater coefficient of expansion than the body.

In order to study the serviceability of this ware in buildings, terra cotta which had been in service 2 to 30 years was examined critically on 535 buildings in practically every large city in the United States east of Kansas City, Mo. It was found that terra cotta must meet certain requirements in climates having freezing weather. Keeping water out of terra cotta structures by proper flashing was found to be beneficial, especially where steel which would otherwise rust is used in the structure.

An investigation of manufacturing methods, with the object of standardizing manufacturing practices in so far as these affect the quality, included a visit to 14 terra cotta plants. The good and poor practices employed by the different plants are being pointed out to the industry. The economic value to the public of improving the quality of the ware in this manner is inestimable.

Other research on terra cotta consists of a study of eight ceramic bodies, including four commercial terra cotta bodies. Twelve different ceramic finishes were used on the specimens and all of the test pieces were made at terra cotta plants in accordance with standard practice. Outdoor service tests are being conducted on specimens molded in the shapes of balusters and coping. In addition to these, laboratory tests are being conducted on the same bodies. It was found that the methods of firing and cooling terra cotta and the types of kilns in which they are fired have a decided influence upon the quality of the ware.

Twenty cements are being investigated to determine their suitability for joining pieces of terra cotta. It was found that some of these cements produced very good joints, the most promising being those of the zinc-oxychloride type.

Adhesion of Mortar to Brick

Comparatively little work has been done on the adhesion of mortar to brick although it has been recognized that the bond between mortar and brick is a factor contributing to the strength and performance of masonry. The problem, therefore, of determining the effect of various kinds of mortars for use with sand-lime brick was taken by up the Bureau.

The total absorption and rate of absorption have been determined for 1100 sand-lime bricks, so that they can be arranged in groups of different absorptive capacities. In general, bricks of the highest total absorption show the most rapid rate of absorbing water.

Tests were made with a 1:3 cement mortar, where the percentage of water was varied, both in the bricks and in the mortar. Where the bricks were used dry, the mortar adhered to the first in contact with it. Where the brick were wet, the mortar adhered to the second brick. The results show that the strength of the bond between cement mortar and bricks is greater when bricks are wet rather than dry and when the mortar itself is quite wet.

SOCIETY OF GLASS TECHNOLOGY

The May meeting of the Society of Glass Technology was held in London and was devoted to a Symposium on the Constitution of Glass. Two sessions were held at both of which members of the Faraday Society, the Optical Society, and the Physical Society and others interested in the subject, were present. At the first session on May 25th, the President, T. C. Moorshead, was in the chair, at the second on May 26th, the chair was occupied by F. G. Donnan, President of the Faraday Society.

The following papers were presented:

I. The Nature and Constitution of Glass

By W. E. S. Turner.—The abnormal properties recently observed in glass when heated in the annealing range (properties including greatly increased thermal expansion, heat absorption, and modification of specific electrical conductivity; and the changes of density and refractive index on heat treating glass) had their counterpart in the charges of plasticity which glass exhibited when remelted or when the raw materials had considerable quantities of moisture or of certain salts present. Two fundamental factors must necessarily be involved in any explanation of these phenomena, namely: molecular complexity and the presence of compounds in glasses. The author proceeded to discuss our knowledge of these two factors in glasses and to suggest explanations for the behavior of glasses.

II. On Glasses as Supercooled Liquids

By G. Tammann.—In the absence of the author, a translation of this paper by J. H. Davidson was presented by F. F. S. Bryson. A discussion of the influence of degree of undercooling, nucleus number, viscosity and other factors on the production of the glassy state. The customary soda-lime-silica glasses might be regarded as ternary mixtures of Na_2SiO_3, $CaSiO_3$, and SiO_2. The two components Na_2SiO_3 and $CaSiO_3$ crystallized readily, as did practically all metasilicates, and this also applied to their mixtures, from which mixed crystals separated. With an excess of silica the nucleus number of these mixed crystals was reduced extraordinarily, so that mixtures with an excess of 8% of silica or over solidified as glasses.

III. On the Constitution and Density of Glass

By A. Q. Tool and E. E. Hill.—This paper was presented for the authors by E. A. Coad-Pryor. The condition of a glass was one which was intermediate between the liquid and solid states. Its condition at ordinary temperatures might be considered as under-cooled not alone with regard to the process of crystallization, usually known as the true solidification, but also with respect to the completion of many processes normal to the vitreous condition. Experimental data on the variation of density and of refractive index of a glass through heat treatment were quoted. The maximum density change observed was 1.10.

IV. The Ternary System Sodium Metasilicate—Calcium Metasilicate-Silica

By G. W. Morey and N. L. Bowen.—This paper was presented for the authors by N. W. Travers. The following new compounds were found and their properties determined: the compound $2Na_2O.CaO.3SiO_2$, which melts incongruently, forming a liquid richer in Na_2SiO_3 and $Na_2O.2CaO.3SiO_2$; the compound $Na_2O.2CaO.3SiO_2$, which has a congruent melting point at 1284°; and the compound $Na_2O.3CaO.6SiO_2$, which melts incongruently at 1045° forming a mixture of wollastonite and a glass containing approximately 15% CaO, 67% SiO_2. The melting point surfaces of the various unary, binary and ternary compounds existing as solid phases had been determined, and the results were given in tables and curves. The relation of the facts discovered to speculations on the constitution of glass was discussed.

V. X-Ray Diffraction Measurements on Some Soda-Lime-Silica Glasses. (A Preliminary Note.)

By R. W. G. Wyckoff and G. W. Morey.—This paper was presented for the authors by Miss V. Dimbleby. In some instances the broad bands thought to be char-

acteristic of glasses had been found. In others, however, narrow bands or lines had been obtained which were as sharp as the lines produced by crystals of colloidal dimensions. Sometimes only one such broad line was observed, in other cases the pattern consisted of several such lines. In still other instances the photograph from a single glass was a composite of lines and broad bands. The positions of the lines were sometimes different from glass to glass, though frequently several glasses agreed in having lines in the same positions. An extended discussion of the results was deferred until many more glasses had been examined.

VI. The Structure of Quartz

By William H. Bragg.—The author observed that the problem of the structure of quartz was one of the first to be attempted some 12 years ago, when the X-rays became applicable to the examination of crystals and a partial solution was obtained. The data, however, did not completely fix the positions of the separate atoms of silicon and oxygen. Four parameters still remained to be determined. One of these referred to the position of the silicon atom, the other three to the positions of the oxygen. The object of the present paper was to describe a new plan based on the fact that quartz changed its structure on passing through 575°. The high-temperature quartz was more symmetrical than the low. A number of considerations showed, however, that the change was not severe and that if the high-temperature structure could be found, the low-temperature form was not very different. The four unknown quantities reduced to one on passing to the high temperature form; the silicon atoms are fixed, and the oxygen atoms must lie on certain straight lines. Attempts to fix the positions of the oxygen atoms could be made, based on intensity measurements. The most probable value showed somewhat unexpectedly that each silicon atom was at the center of a regular tetrahedron of which the four corners were occupied by oxygen atoms. If it was assumed that the low-temperature quartz was not very different from the high-temperature quartz as determined in this way, the various twinnings of quartz were readily accounted for.

VII. The Viscosity of Glass

By Vaughan H. Stott.—The results of a critical study of the measurements of E. W. Washburn and G. Shelton, and of S. English has been recently published by H. Le Chatelier. In the present paper these measurements were reconsidered in conjunction with some additional determinations which had been carried out at the National Physical Laboratory. If it was desired to obtain final relations between viscosity and composition, in which errors due to impurities or inaccurate compositions generally, were not considerably greater than the errors of the viscosity determinations themselves, it would be necessary to prepare the glasses from materials of known purity and melt them without contamination. This procedure, which at present precluded the melting of large pieces of glass, would limit considerably the design of viscosimeters.

MEETING OF THE ST. LOUIS DISTRICT ENAMELERS CLUB

The members proving again their interest and confidence in the Club attended in a number of 31, also three guests, two of whom, Messrs. Eppstein and Wilson, representing the local Laclede Gas Light Company, and the speaker of the evening, R. A. Weaver, of Cleveland, Ohio.

Mr. Weaver, or just "BOB," as the enamelers will know him, has with his Friendship, we may say, honored the Club, and to him the Club extends its sincere thanks and appreciation for all he has done toward getting it known, with reference to the *Enamelist*.

Preceding the regular business meeting a dinner was served, the only complaint being that it was not served in Belleville. The Belleville Boys, however, tried to conceal their feelings by reading to the Club a paper on "The Function of Manganese Dioxide in Ground Coat Enamels," and succeeded brilliantly, because the subject opened wide and lively discussion, thus setting in the background everything else.

Gus Oesterle and F. S. Markert of the Belleville Enameling & Stamping Company well deserve credit for this excellent paper, of which the contents in short follow:

Manganese dioxide is generally used in the ground coat enamel in the amount of from 1–3% to the raw batch weight. It acts chiefly as a coloring agent and is economical to use in replacing the cobalt and nickel oxides, which are much more expensive. Dependent upon the amount used, manganese dioxide varies in color from a drab green to a violet color. Also the use of borax and bone ash with it has influence over the color of the ground coat enamel. In order to obtain a uniform and dark colored ground coat, cobalt, or nickel oxide should be added.

Manganese dioxide affects the physical properties of the enamels as follows: It gives good gloss to the enamel. Harder enamel is obtained with less danger of overfiring. It reduces the coefficient of expansion of the glass it is used with. Adhesion of the ground coat to the steel is same as when cobalt is used. Has no apparent effect on chipping of the enamel.

The paper has been based and worked out on the experience Mr. Oesterle has had in his shop.

Another paper on dipping was read by B. T. Euler of the Buck Stove & Range Company describing their dipping devices and experience.

Their method to test enamel for proper set, which has proved satisfactory, follows:

Using a piece of steel exactly two feet square, should be dipped in ground coat enamel when particularly good results are obtained. If the enamel has drained the piece of steel should be carefully weighed to the accuracy of $^1/_{16}$ ounce. Having arrived at the weight of it, it will be easy to set up the enamel, using the same piece of steel for testing the enamel about twice a day.

Borax solution should not be used in the ground coat enamel, but instead add 1% crystal borax to the mill.

Reports of the various committees were heard. F. Stretch, Chairman of the Membership Committee announced that he received from H. J. Swope, general manager of the Economy Enameling Company, Quincy, Ill., application for membership. The application was unanimously accepted and with great pleasure a new member's name has been added to the roster of the Club.

Section "Q" opened every field of discussion as usual. The most important question is still the oldest one "When will the time come when FISHSCALES will be obsolete?" The question was not answered entirely satisfactory and there is no doubt but that it will come up again.

The meeting was adjourned for the hot summer months until September.

CALENDAR OF CONVENTIONS

Organization	Date	Place
Am. Assn. Advancement of Science	Dec. 28–Jan. 2	Kansas City, Mo.
AMERICAN CERAMIC SOCIETY		
(Annual Meeting)	Feb. 8–13, 1926	Atlanta, Ga.
(Fall Meeting)	Oct. 1, 1925	New York City
Am. Electrochemical Society	Sept. 24–26, 1925	Chattanooga, Tenn.
Am. Engineering Council	Jan., 1926	

Organization	Date	Place
Am. Foundrymen's Association	Oct. 5–9, 1925	Syracuse, N. Y.
Am. Gas. Association	Oct. 12–16, 1925	Atlantic City, N. J.
Am. Inst. of Min. and Met. Engineers	Aug. 31–Sept. 5, 1925	Salt Lake City, Utah
Am. Soc. of Mechanical Engineers	Nov. 30–Dec. 3, 1925	New York City
Am. Zinc Institute	April 27–28, 1926	St. Louis, Mo.
Assn. Iron and Steel Elec. Engineers	Sept., 1925	Philadelphia, Pa.
Coal Mining Institute of America	Dec. 9–11, 1925	Pittsburgh, Pa.
Common Brick Manufacturers Assn.	Feb. 22–26, 1926	New Orleans, La.
Mining and Met. Society of America	Jan. 12, 1926	New York City
Natl. Association of Manufacturers	Oct. 26–28, 1925	St. Louis, Mo.
Natl. Exposition of Power and Mechanical Engineers	Nov. 30–Dec. 5, 1925	New York City
Natl. Exposition of Chem. Industries	Sept. 28–Oct. 3, 1925	New York City
Natl. Paving Brick Mfrs. Assn.	Jan., 1926	
Natl. Safety Council	Sept. 28–Oct. 2, 1925	Cleveland, O.
Optical Society of America	Oct., 1925	Ithaca, N. Y.
Sand-Lime Brick Association	Feb. 9–15, 1926	New Orleans, La.
Natl. Society for Vocational Education	Dec. 3–5, 1925	Cleveland, Ohio
Natl. Exposition of Coal Mining Machinery	Dec. 2–5, 1925	Cincinnati, O.

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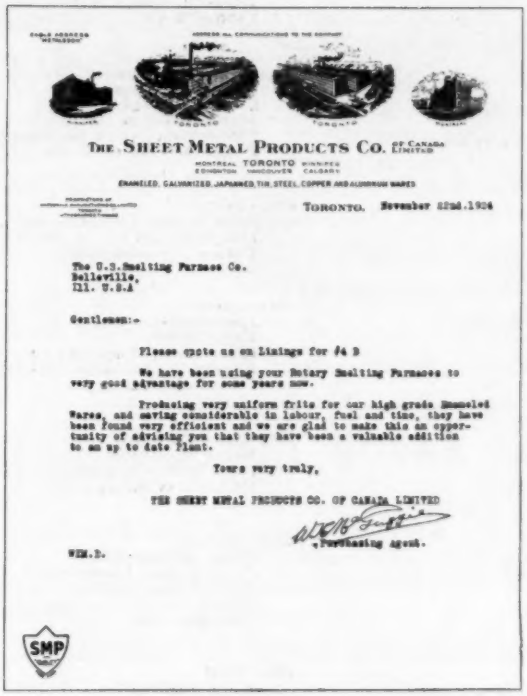

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B

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Innis, Speiden & Co.

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C

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Clay Cleaning Machinery
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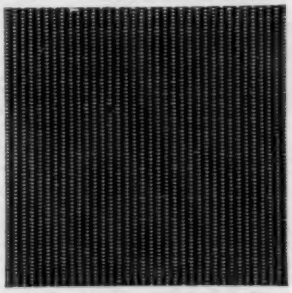

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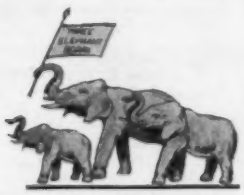

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Drying Machinery
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E

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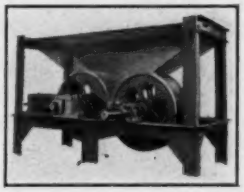

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F

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G

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H

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I

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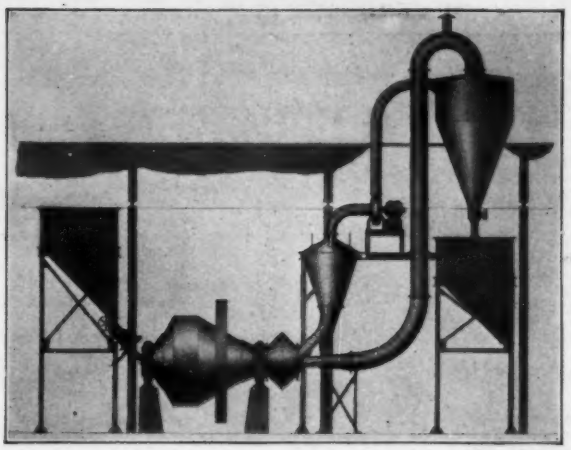

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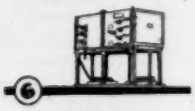

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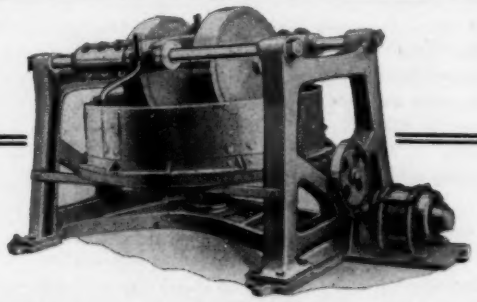

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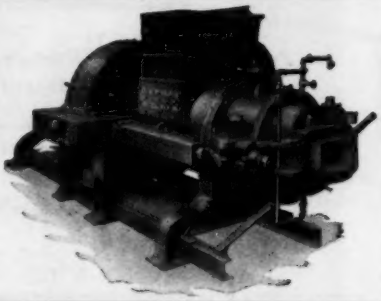

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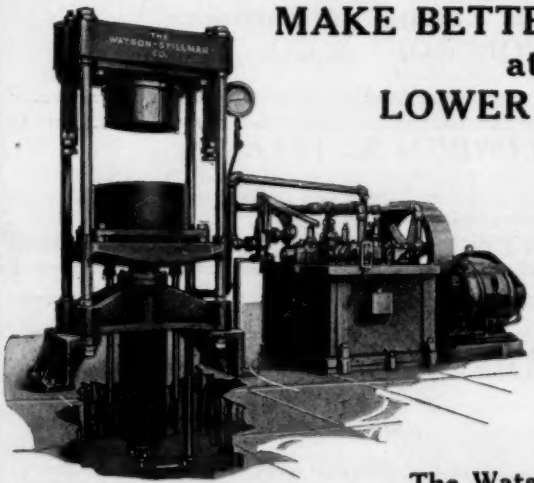

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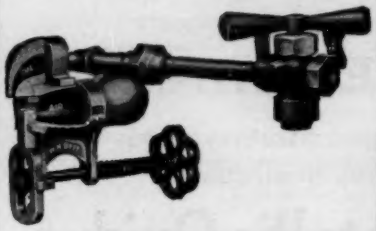

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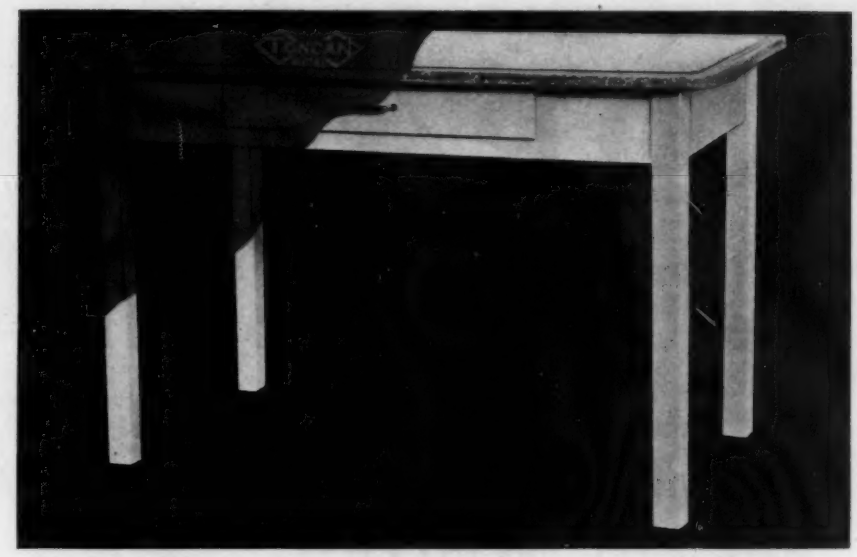
The Leeds & Northrup Co. have just announced a new edition of their Catalog No. 87 "Potentiometer Pyrometers." This catalog is a revise of the 1924 edition and contains items of interest to any ceramic man and should prove a valuable addition to the library of any ceramic plant.

Mr. Fred Runge, formerly with The Ferro Enameling Company of Cleveland, Ohio, is now with the Andes Range and Furnace Corporation, Geneva, New York.

The Beach Enameling Company of Ottawa, Canada, has just completed installing a new porcelain enameling department. Mr. Clyde Thomas, formerly with Findlay Brothers Company of Canada will run the Beach Enameling plant.



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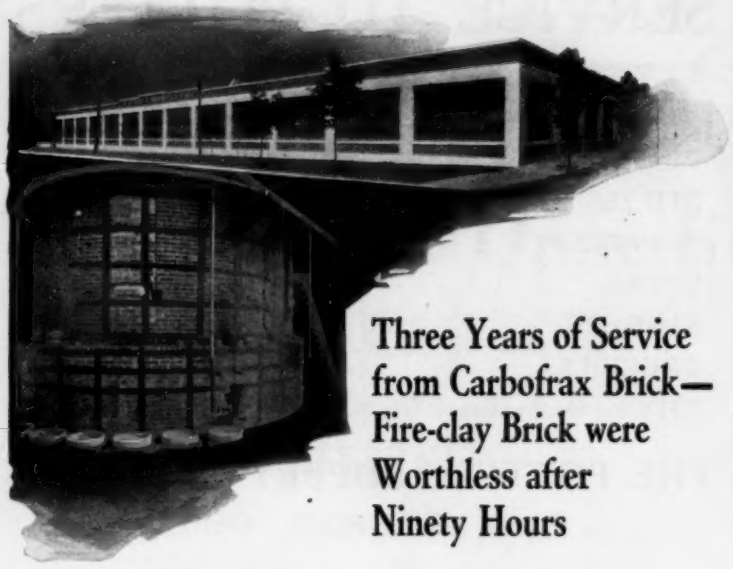

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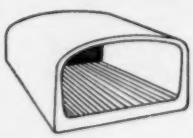

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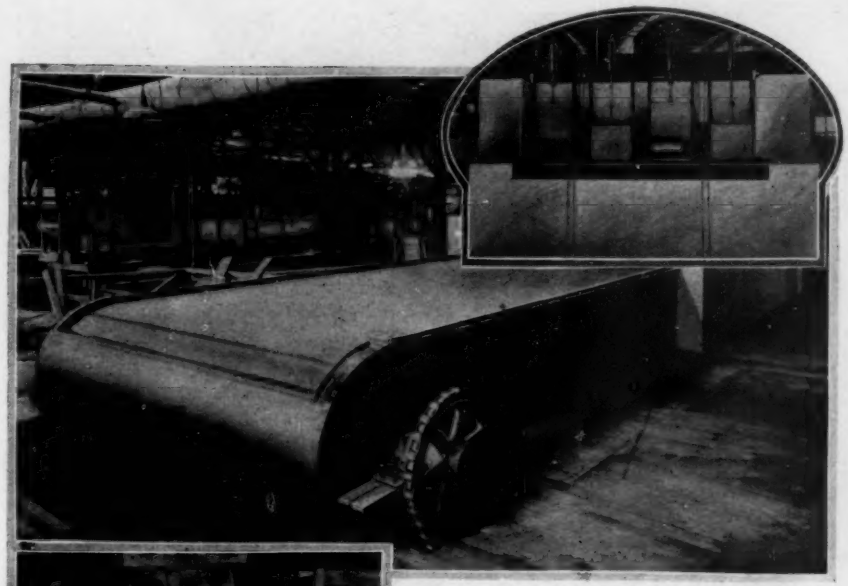

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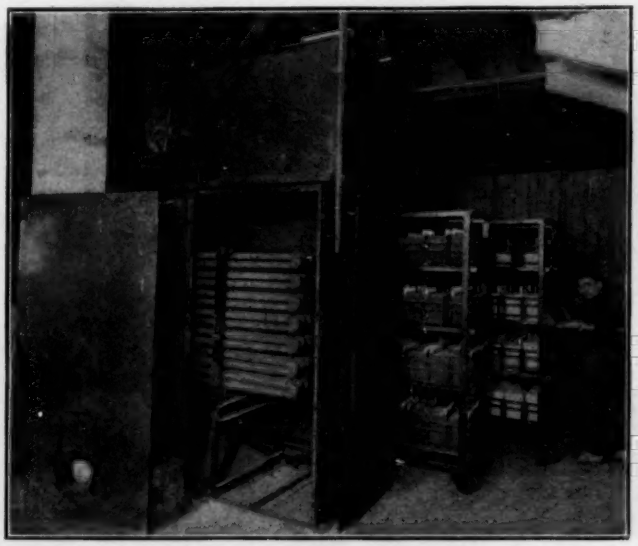

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